BOOK OF ABSTRACTS

London-Paris Bachelier Workshop

September 15–16, 2022, Paris

Invited Talks

Gaussian Principal-Agent problems with memory

Eduardo Abi Jaber

Ecole Polytechnique

Are linear contracts still optimal? (joint with Stéphane Villeneuve.)

Option Markets in the Age of Robinhood (and before)

Albina Danilova

London School of Economics

We consider an economy in which some agents do not continuously hedge their position in derivative assets using the underlying assets market – i.e. we study the effects of an imbalanced derivate market. We show that, even in the presence of complete markets, the imbalance significantly alters the equilibrium price process of the underlying assets: risk premia and volatility become stochastically time varying, hence option implied volatility is characterized by smile and smirk patterns, momentum-like price dynamics arise as well as price spillovers across under- lying assets. Moreover, the derivative imbalance generates self-fulfilling equilibria, e.g. if the imbalance takes the form of a bet on an increase in asset volatility, then the equilibrium volatility does increase. Finally, since our formulation is extremely general, our results also apply to segmented markets where some investments are achievable only via financial intermediation.

Non–regular McKean–Vlasov equations and calibration problem in local stochastic volatility models

Mao Fabrice Djete

Ecole Polytechnique

In order to deal with the question of the existence of a calibrated local stochastic volatility model in finance, we investigate a class of McKean–Vlasov equations where a minimal continuity assumption is imposed on the coefficients. Namely, the drift coefficient and, in particular, the volatility coefficient are not necessarily continuous in the measure variable for the Wasserstein topology. In this paper, we provide an existence result and show an approximation by N–particle system or propagation of chaos for this type of McKean–Vlasov equations. As a direct result, we are able to deduce the existence of a calibrated local stochastic volatility model for an appropriate choice of stochastic volatility parameters. The associated propagation of chaos result is also proved.

Learning equilibria in mean field games

Romuald Elie

Deepmind & Université Gustave Eiffel

We will present different approaches and algorithms for learning equilibria in mean field games. In particular, we will consider frameworks where uniqueness of Nash does not hold, and see how one can approximate alternative solution concepts, such as Correlated or Coarse correlated equilibria. Applications to animal flocking, vehicule routing as well as connections with exploration problems in Reinforcement learning will also be presented.

Learning with signatures

Adeline Fermanian
Mines ParisTech

Modern applications of artificial intelligence lead to high-dimensional multivariate temporal data that pose many challenges. Through a geometric approach to data flows, the notion of signature, a representation of a process as an infinite vector of its iterated integrals, is a promising tool. Its properties, developed in the context of rough path theory, make it a good candidate to play the role of features, then injected in learning algorithms. If the definition of the signature goes back to the work of Chen (1960), its use in machine learning is recent, and many questions remain to be explored. In this talk, we will give a quick overview of the signature definition and properties, continue with a discussion on how it can be used in a learning context, and conclude by focusing on one specific problems: estimation in a linear regression setting.

Bridging socioeconomic pathways of carbon emission and credit risk

Ying Jiao
Université Claude Bernard Lyon 1

As the world is facing global climate changes, the Intergovernmental Panel on Climate Change (IPCC) has set the idealized carbon-neutral scenario around 2050. In the meantime, many carbon reduction scenarios, known as Shared Socioeconomic Pathways (SSPs) have been proposed in the literature. We aim to investigates the impact of transition risk on a firm's low-carbon production. On the one hand, we consider a firm that searches to optimize its emission level under the double objectives of maximizing its production profit and respecting the emission mitigation scenarios. Solving the penalized optimization problem provides the optimal emission according to a given SSP benchmark. On the other hand, such transitions affect the firm's credit risk. We model the default time by using the structural default approach and are particularly concerned with how the adopted strategies following different SSPs scenarios may influence the firm's default probability. Finally we propose possible extension of the model to a large portfolio of climate concerned firms and discuss numerical methods to compute cumulative losses. This is a joint work with Florian Bourgey and Emmanuel Gobet.

Optimal control of path-dependent McKean-Vlasov SDEs in infinite dimension

Idris Kharroubi

Sorbonne Université

We study the optimal control of path-dependent McKean-Vlasov equations valued in Hilbert spaces motivated by non Markovian mean-field models driven by stochastic PDEs. We first establish the well-posedness of the state equation, and then we prove the dynamic programming principle (DPP) in such a general framework. The crucial law invariance property of the value function V is rigorously obtained, which means that V can be viewed as a function on the Wasserstein space of probability measures on the set of continuous functions valued in Hilbert space. We then define a notion of pathwise measure derivative, which extends the Wasserstein derivative due to Lions [Cours au collège de france: Théorie des jeux à champ moyens. Audio Conference, 2006-2012], and prove a related functional Itô formula in the spirit of Dupire [Functional itô calculus. SSRN: 1435551, 2009] and Wu and Zhang [Viscosity solutions to parabolic master equations and McKean-Vlasov SDEs with closed-loop controls. Ann. Appl. Probab., 30(2):936–986, 2020]. The Master Bellman equation is derived from the DPP by means of a suitable notion of viscosity solution. We provide different formulations and simplifications of such a Bellman equation notably in the special case when there is no dependence on the law of the control. This talk is based on a joint work with Andrea Cosso, Fausto Gozzi, Huyên Pham and Mauro Rosestolato.

Optimality in General Propagator Models with Alpha Signals

Eyal Neuman

Imperial College London

We consider an optimal liquidation problem with a linear transient price impact, induced by a Volterra-type kernel, while also taking into account a general price predicting signal. We formulate this problem as minimization of a cost-risk functional over a class of absolutely continuous and signal-adaptive strategies. By identifying the problem as an infinite dimensional stochastic control problem, we characterize the value function in terms of a solution to an L^2-valued backward stochastic differential equations and an to an operator-valued Riccati equation, and derive an explicit optimal trading strategy. Our results also includes

the case of a singular power-law price impact kernel. This is a joint work with Eduardo Abi-Jaber.

Periodic portfolio selection (with quasi-hyperbolic discounting)

Alex Tse

University College London

I will present a continuous-time portfolio selection problem faced by an agent with S-shaped preference who maximizes the utilities derived from the portfolio's periodic performance over an infinite horizon. I will first outline the solution method under a baseline setup. Then I will introduce a time-inconsistent version of the problem featuring quasi-hyperbolic discounting. If the agent is sophisticated who seeks a consistent planning strategy, the problem can then be analyzed via a static mean field game where theoretical characterization of the optimal strategy is provided. This talk is based on two different joint works with Harry Zheng and Yushi Hamaguchi respectively.

Neural networks for high-dimensional parametric option pricing: Expression rates and exposure evaluations

Linus Wunderlich

Queen Mary University London

In this talk we will discuss the deep parametric PDE method for parametric option pricing in high dimensions, underlying theoretical results for neural networks and an application in risk management.

The deep parametric PDE method uses deep neural networks to solve parametric partial differential equations, such as those arising in option pricing. Especially for a large number of risk factors, the efficiency of neural networks for high dimensional problems is beneficial. We investigate this efficiency theoretically by proving new approximation rates for networks with smooth activation functions.

Finally an application to exposure calculations numerically confirms the efficiency of the method. We compute expected exposures and potential future exposures for up to 10 underlying assets and compare the performance to a competing sparse grid method.

Exploration-exploitation trade-off for continuous-time reinforcement learning

Yufei Zhang

London School of Economics

Recently, reinforcement learning (RL) has attracted substantial research interests. Much of the attention and success, however, has been for the discrete-time setting. Continuous-time RL, despite its natural analytical connection to stochastic controls, has been largely unexplored and with limited progress. In particular, characterising sample efficiency for continuous-time RL algorithms remains a challenging and open problem.

In this talk, we develop a framework to analyse model-based reinforcement learning in the episodic setting. We then apply it to optimise exploration-exploitation trade-off for linear-convex RL problems, and report sublinear (or even logarithmic) regret bounds for a class of learning algorithms inspired by filtering theory. The approach is probabilistic, involving analysing learning efficiency using concentration inequalities for correlated continuous-time observations, and applying stochastic control theory to quantify the performance gap between applying greedy policies derived from estimated and true models.

Contributed Talks

A Theoretical Analysis of Guyon's Volatility Model

Ofelia Bonesini

Univ. Padova

We provide a thorough analysis of the path-dependent volatility model introduced by Guyon, proving existence and uniqueness of a strong solution, characterising its behaviour at boundary points, providing asymptotic closed-form option prices as well as deriving small-time behaviour estimates. This is a joint work with Doctor Chloé Lacombe and Professor Antoine Jacquier.

Diffusive limit approximation of pure jump optimal ergodic control problems

Lorenzo Croissant

CEREMADE, Université Paris Dauphine-PSL and Criteo AI Lab

Motivated by the design of fast reinforcement learning algorithms in the context of high-frequency ad-auctions, we study the diffusive limit of a class of pure-jump ergodic stochastic control problems. We show that, whenever the intensity of jumps is large enough, the approximation error is governed by the Hölder continuity of the Hessian matrix of the solution to the limit ergodic partial differential equation. Using the limit approximation can lead to significant reduction in the numerical resolution cost.

Complexity Reduction for Exposure Measurements of Financial Derivatives

Domagoj Demeterfi

Queen Mary University London

The key element in quantifying counterparty credit risk, namely, estimation of exposure measures, requires many, often expensive, evaluations of the pricing functions. This talk explores the potential of complexity reduction techniques in exposure measurements. The work is motivated by the fact that the pricing functions repeatedly evaluated in the calculations are typically sufficiently regular and so admit accurate approximations by simpler functions. We investigate the implications of complexity reduction in a developed theoretical framework. We show that an error in any exposure measurement induced by complexity reduction is not greater than an error of the underlying pricing function approximation measured in the uniform norm. On the other hand, we show that a small L^p norm of the function approximation error does not guarantee an equally small error for a general exposure measure. We consider the Chebyshev interpolation as a particular instance of the approximation method used for a complexity reduction, given its appealing theoretical and practical properties for applications in finance. Conducted numerical experiments covering several financial derivatives in different option pricing setups confirm the effectiveness of the approach. Obtained theoretical and practical results suggest great potential benefits and uncover possible pitfalls of the complexity reduction approach to exposure measurements.

Equilibrium Asset Pricing with stochastic investment opportunities and proportional transactional costs

Justin Gwee

London School of Economics and Political Science

In view of the increasing automatisation of financial markets, correctly specifying the tradeoff between frequent trading and transaction costs becomes paramount. In this talk, we consider the impact of proportional transaction costs on risk-sharing equilibria between two agents with mean-variance preferences. The state of the economy is modelled by an underlying diffusion process leading to stochastic investment opportunities for the agents. Here, our model allows us to observe new effects resulting from the interplay between the transaction costs and

the stochastic investment opportunities. This includes solving a two-dimensional free boundary problem similar to those arising from singular stochastic control problems and generalises earlier results by Gonon, Muhle-Karbe and Shi (2021) that have been established in a model with constant coefficients. The talk is based on joint work with Christoph Czichowsky and Mihalis Zervos.

Linear Quadratic Principal Multi-Agent Incentive Problems with Applications to Development of Renewable Energy

Annika Kemper

Center for Mathematical Economics at Bielefeld University (Germany)

In this work we provide a class of tractable Principal Multi-Agent incentives problems. We follow the resolution methodology of Cvitanić et al. (2018) in an extended linear-quadratic setting with exponential utilities and a multi-dimensional state process of Ornstein-Uhlenbeck type. Our analysis results in a closed-form second-best contract being of rebate form. Moreover, we investigate the optimal regulation of energy production reflecting the long-term goals of the Paris Climate Agreement. In particular, we provide optimal regulatory incentives in a monopolistic and competitive Two-Agent setting to encourage green investments and limit carbon emissions, while simultaneously stabilizing the total energy production. A numerical study highlights the impact of the designed second-best contract in comparison to business as usual. In particular, we illustrate how to encourage renewable investments, how to avoid carbon emissions, how to ensure a stable production, and how competition affects incentives.

An Optimal stopping Mean Field Game with common noise model for energy transition under scenario uncertainty.

Marcos Leutscher

CREST, ENSAE, Institut Polytechnique de Paris

We propose a discrete time mean-field game model for the industry dynamics in the electricity market. The market is subject to common noise in the form of random shocks in the carbon price. These shocks depend on a macroeconomic scenario which is not observed by the agents, but can be partially deduced from the frequency of the shocks. Due to this partial observation feature, the common noise is non-Markovian. We consider two classes of agents: conventional producers and renewable producers. The former choose an optimal moment to exit the market and the latter choose an optimal moment to enter the market by building a renewable plant. The agents interact through the market price which is determined by a merit order mechanism, involving an exogenous stochastic demand process. We study the existence of Nash equilibria in the resulting mean-field game problem of optimal stopping with common noise, developing a novel linear programming approach for these problems. We illustrate our model by an example inspired in the UK electricity market. Joint work with Roxana Dumitrescu and Peter Tankov.

Impulse Control of a Linear Diffusion: an Explicitly Solvable Problem

Zhesheng Liu

London School of Economics

We consider a stochastic impulse control problem that is motivated by several applications in areas such as the optimal cashflow management or the optimal exploitation of a natural resource. In particular, we consider a stochastic system whose uncontrolled state dynamics are modelled by a non-explosive positive linear diffusion. The control that can be applied to this system takes the form of one-sided impulsive action. The objective of the control problem is to maximise a discounted performance criterion that rewards the effect of control action but involves a fixed cost at each time of a control intervention. We derive the complete solution to this problem under general assumptions. It turns out that the solution can take four qualitatively different forms. In two of the four cases, there exist only ε-optimal control strategies.

A Stochastic Target Problem for Branching Diffusions

Antonio Ocello

LPSM – Sorbonne Université

We consider an optimal stochastic target problem for branching diffusion processes. This problem consists in finding the minimal condition for which a control allows the underlying branching process to reach a target set at a finite terminal time for each of its branches. This problem is motivated by an example from fintech where we look for the super-replication price of options on blockchain based cryptocurrencies. We first state a dynamic programming principle for the value function of the stochastic target problem. We then show that the value function can be reduced to a new function with a finite dimensional argument by a so called branching property. Under wide conditions, this last function is shown to be the unique viscosity solution to an HJB variational inequality.

Fast Calibration using Complex-Step Sobolev Training

Bouazza Saadeddine

LaMME, Univ. Evry / Crédit Agricole CIB

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 piece-wise 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.

Diffusion of carbon price in a credit portfolio through macroeconomic factors

Lionel Sopgoui

LPSM, Univ. Paris Cité ; Imperial College London ; Groupe BPCE

We study how the introduction of a carbon price in a closed economy propagates in a credit portfolio and precisely describe how carbon price dynamics affects credit risk variables (or metrics) such as probability of default, expected and unexpected loss. We adapt a classical monetary model (Monetary policy, inflation, and the business cycle: an introduction to the new Keynesian framework and its applications, Galì, 2015) to take into account two carbon taxes (one on firms' production and one on households' consumption) (Climate-related scenarios for financial stability assessment: an application to France, Allen et al., 2020), which yields a closed-form relationship between carbon taxes – calibrated on realised GHG emissions and on carbon prices – and real GDP growth. We then introduce carbon price dynamics in a stochastic multi-sectoral model, where taxes are calibrated of sectoral households and firms' greenhouse gases emissions. This yields the sensitivity of firms' production and households' consumption of each sector to carbon price and the relationships between sectors. This allows us to analyse the short-term effects (quarterly or annually) of carbon taxes as opposed to standard Integrated Assessment Models (such as REMIND (Description of the REMIND model (Version 1.6), Luderer et al., 2015)), which are not only deterministic but only capture long-term trends of climate transition policy. Finally, we use a discount cash flow methodology (Problems with the discounted cash flow method: discrepancy between theory and practice, Seijdell, 2015) to compute firms' values and use them in the Merton model to describe the deformations of the credit risk metrics with a carbon price. We observe that, on the one hand, the introduction of a carbon price not only increases banking fees charged to clients (materialised by the provisions via the expected loss) but will also reduce banks' profitability (via the economic capital that is calculated from the unexpected loss). In addition the added randomness of our model adds extra flexibility to compute confidence intervals for a more accurate risk assessment. We also compute the sensitivities of the credit risk metrics with respect to changes in the carbon price, yielding further criteria for a more accurate assessment of climate risk in a credit portfolio. This work provides a preliminary methodology to calculate the evolution of credit risk metrics of a multi-sectorial credit portfolio, starting from a climate transition scenario described by a carbon price.

Convergence rate of RBSDE by penalisation method and its Monte-Carlo approximation

Wanqing Wang

Ecole Polytechnique

In this paper, we study the numerical solution $(\hat{Y}, \hat{Z}, \hat{K})$ for Reflected Backward Stochastic Equations (RBSDEs in short) by the penalisation approach and we apply this on the pricing problem of American option. Considering the barrier as a generalised Itô process (which is natural for Call and Put), we first show that the penalisation term can converge to 0 at order 1 or $\frac{1}{2}$ with respect to the constant of penalty and then we deduce that the solution of penalised BSDE can converge to the one of RBSDE at respectively the same order as the penalisation term. Followed by the results in the continuous case, when the generator does not depend on Z, the error analysis is also established for the discrete implicite scheme of PBSDE and in the end, using the Monte-Carlo method, we show numerically that the error decrease faster than the order we have proved.