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BOOK OF ABSTRACTS

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Contents

Stochastic control and games with memory

Eduardo Abi Jaber
Ecole Polytechnique

We provide analytic solutions for a large class of stochastic control and games of Linear-Quadratic Volterra type. Such class of models allow to incorporate path-dependency, delays and persistence in the state variables and controls. We also establish a link of our solutions with infinite dimensional operator-valued Riccati equation. We illustrate our results on an optimal liquidation problem in mathematical finance where the agents transactions create transient price impact driven by a Volterra-type propagator along with temporary price impact and signals.
This is a joint work with Eyal Neuman and Moritz Voss.

A new notion of maximal quasimonotonicity

Monica Bianchi
Università Cattolica del Sacro Cuore

A new notion of maximality for quasimonotone operators based both on the notion of quasimonotone polar of an operator T and on its behaviour at the points in the interior of the effective domain of T, is introduced.

We show how this property is enjoyed, in particular, by the adjusted normal cone operator to the sublevel sets of a quasiconvex function, provided suitable assumptions on the minima are satisfied.
This is a joint work with Nicolas Hadjisavvas and Rita Pini.

Equilibrium selection via approximation and penalization

Giancarlo Bigi
Università di Pisa

The selection of equilibria is a central issue in the management of multi-agent systems that can be partially controlled. Once the system has been modelled, the selection can be performed through an hierarchical program whose lower-level describes the equilibria of the system and the upper-level explicitly addresses the selection criterion through a suitable objective function. These hierarchical programs are simpler than more general bilevel structures as the lower-level problems are non-parametric with respect to the upper level variables. In order to tackle them, suitable approximated versions are introduced. On the one hand, the approximation does not perturb the original [exact] program too much and allows for some additional flexibility in the choice. On the other hand, it allows relying on suitable exact penalty schemes by recovering those regularity conditions that the original problems do not satisfy. These penalization approaches are addressed in detail and their convergence properties are established.

Correlated equilibria for mean field games with progressive strategies

Ofelia Bonesini
Imperial College London

In a discrete space and time framework, we study the mean field game limit for a class of symmetric N-player games based on the notion of correlated equilibrium. We give a definition of correlated solution that allows to construct approximate N-player correlated equilibria that are robust with respect to progressive deviations. We illustrate our definition by way of an example with explicit solutions.
This is a joint work with Luciano Campi and Markus Fischer.

Rank-two programs involving linear fractional functions

Riccardo Cambini
Università di Pisa

Linear fractional functions are widely used in applications, for example in DEA models and efficiency models. In this light, rank-two program involving linear fractional functions can be used to study bicriteria efficiency models and their scalarizations.

The aim of this talk is to present a solution method for rank-two programs involving linear fractional functions, as well as suitable underestimation functions, partitioning criteria and a detailed computational experience.

The presented results extend the ones already published in:

- Cambini R. (2020), "Underestimation functions for a rank-two partitioning method"", Decisions in Economics and Finance, vol.43, n.2, pp.465-489. ISSN 1593-8883. DOI: 10.1007/s10203-020-00288-6.
- Cambini R. and I. Venturi (2021), "A new solution method for a class of large dimension rank-two nonconvex programs"", IMA Journal of Management Mathematics, vol.32, n.2, pp.115-137. ISSN 1471-678X. DOI: 10.1093/imaman/dpaa001.

This is a joint work with Giovanna D'Inverno.

Optimal water tariffs for domestic, agricultural and industrial use

Andrea Caravaggio
Università di Foggia

Consider a water supplier who determines sales rates with the goals of maximizing profits, protecting consumer welfare and ensuring adequate future water supplies. Buyers are differentiated and can use the water for domestic, agricultural and industrial purposes. We propose a leader-follower finite-horizon differential game. The leader (the water supplier) determines the selling price and the followers (consumers) react by requesting their optimal amount of water. We calculate a Stackelberg feedback equilibrium assuming that all user demand is satisfied (interior equilibrium). We compare two different tariff schemes: linear tariffs (the price paid is a multiple of the volume of water purchased), and increasing block tariffs (the unit price is

lower for quantities of water that do not exceed a fixed threshold). We show that block pricing is never optimal and linear pricing is always preferred.
This is a joint work with Luigi De Cesare and Andrea Di Liddo.

A continuity result for the adjusted normal cone operator

Marco Castellani
Università dell'Aquila

The concept of adjusted sublevel set for a quasiconvex function was introduced by Aussel and Hadjisavvas in 2005 and the local existence of a norm-to-weak* upper semicontinuous base-valued submap of the normal operator associated to the adjusted sublevel set was proved. When the space is finite dimensional, a globally defined upper semicontinuous base-valued submap is obtained taking the intersection of the unit sphere, which is compact, with the normal operator, which is closed. Unfortunately, this technique does not work in the infinite dimensional case. We propose a partition of unity technique to overcome this problem in Banach spaces. Application is given to a quasiconvex quasioptimization problem through the use of a new existence result for generalized quasivariational inequalities which is based on the Schauder fixed point theorem.
This is a joint work with Massimiliano Giuli.

Strategic Investment under Uncertainty with First- and Second-mover Advantages

Min Dai
Hong Kong Polytechnic University

We analyze a duopoly real-option entry game where the second mover has a cost advantage over the first mover. The equilibrium solution features five regions. In addition to the option-value-of-waiting and competing-to-enter (first-mover-advantage) regions (Fudenberg and Tirole, 1985; Grenadier, 1996), three new regions appear due to the second-mover advantage: a waiting-to-be-Follower region and two disconnected probabilistic-entry regions. Only when market demand is very high does Follower immediately enter after Leader does. The second-mover advantage causes firms to use state-contingent mixed strategies, significantly delaying their entry timing. Our model generates new predictions, e.g., entry likelihood is non-monotonic in market demand.

This is a joint work with Zhaoli Jiang and Neng Wang.

Nonzero-sum stochastic impulse games with an application in competitive retail energy markets

M'hamed Gaïgi
ENIT-LAMSIN, Université de Tunis El Manar

We study a nonzero-sum stochastic differential game with both players adopting impulse controls, on a finite time horizon. The objective of each player is to maximize her total expected discounted profits. The resolution methodology relies on the connection between Nash equilibrium and the corresponding system of quasi-variational inequalities (QVIs in short). We prove, by means of the weak dynamic programming principle for the stochastic differential game, that the value function of each player is a constrained viscosity solution to the associated QVIs system in the class of linear growth functions. We also introduce a family of value functions converging to our value function of each player, and which is characterized as the unique constrained viscosity solutions of an approximation of our QVIs system. This convergence result is useful for numerical purpose. We apply a probabilistic numerical scheme which approximates the solution of the QVIs system to the case of the competition between two electricity retailers. We show how our model reproduces the qualitative behaviour of electricity retail competition.
This is a joint work with René Aïd; Lamia Ben Ajmia and Mohamed Mnif.

A Dam Management Problem with Energy Production as an Optimal Switching Problem

Elisa Giovannini
Università di Firenze

We consider the optimal control for a dam, for which power production is operating, but the water level must be kept under control. The water level inside the basin cannot exceed a certain threshold for safety reasons, but at the same time cannot decrease below another threshold in order to keep power production active. The problem can be formulated as an optimal switching problem with constraints, for which we provide existence results and propose some numerical methods for approximating the solution. We shall illustrate by numerical examples the main achievements of the present approach.
This is a joint work with Simone Scotti.

Linesearch-free adaptive proximal algorithms for convex optimization under local Lipschitz continuity of the gradient

Puya Latafat
KU Leuven

Gradient-based proximal algorithms have traditionally been studied under global Lipschitz differentiability requirements. The standard approach to widen their applicability and to reduce conservatism typically involves backtracking linesearch procedures. Extending recent advancements in the smooth setting, we show how for convex problems it is possible to avoid backtrackings altogether and compute the stepsizes adaptively without function evaluations. We demonstrate this with an adaptive primal-dual three-term splitting method that includes proximal gradient method as special case.
This is a joint work with Andreas Themelis; Lorenzo Stella and Panagiotis Patrinos.

AK model on Network

Marta Leocata
Scuola Normale Superiore

We study an spatial economic growth model where the space variable lies in a network and is written as an optimal control problem in finite dimension with state constraints. This is different from the related literature where the space belongs to S^1, S^2 or an open subset of it giving rise to infinite dimensional optimal control problems.
The main motivation is that this choice reflects the structure of spatial economic data and should then allow for a more efficient numerical implementation and calibration of the results.
The resulting optimal control problem with state constraints is studied finding a regularity result for the value function which sets up the basis to study the optimal strategies. Moreover, we characterize a class of cases where an explicit solution can be found and we discuss the two node case.
This is a joint work with Alessandro Calvia; Fausto Gozzi; Georgios Papayiannis; Anastasios Xepapadeas and Athanasios Yannacopoulos.

Robust Equilibrium Strategy for Mean-Variance Portfolio Selection

Mengge Li
National University of Singapore

The classical mean-variance portfolio selection problem induces time-inconsistent strategies (see Zhou and Li (2000)). To solve this time-inconsistency, Basak and Chabakauri (2010) introduce the game theoretical approach and look for sub-game perfect Nash equilibrium strategies. It is found this strategy can be solved from the corresponding partial differential equations (PDE) system. However, when introducing other factors, e.g., the robust control, into this model, the relation between the equilibrium strategy and the PDE system is unclear. In this paper, we consider a general dynamic mean-variance framework and propose a novel definition of the *robust equilibrium strategy*. Under our definition, a classical solution to the corresponding PDE system implies a robust equilibrium strategy. We then explicitly solve for some special examples.
This is a joint work with Qian Shuaijie and Zhou Chao.

Nowcasting corporate leverage

Federico Maglione
Università di Firenze

We develop a nowcasting procedure to generate a high frequency estimate of the firm-level market value of leverage. We estimate a contingent claims model using a non-linear Kalman filter together with daily data on credit default swaps and equity prices for a sample of US non financial-firms. We show that the market value of leverage is (i) systematically lower than the book leverage, (ii) highly countercyclical, and (iii) spikes during high stock market volatility clusters. Additionally, fluctuations in market leverage tend to anticipate significant increases in the book leverage and, contrary to book leverage, they do not exhibit any significant time trend. The output of our analysis can be used by Central Banks and regulatory authorities to adjust and calibrate their responses to upcoming, dramatic events on the basis of timely and frequent information about the current state of corporate liabilities.
This is a joint work with Raffaele Corvino and Berardino Palazzo.

A stochastic variational approach for an electricity market equilibrium problem

Monica Milasi
Università di Messina

The aim of this talk is to study an electricity market model. The decision-making problem evolves in $T + 1$ stages and, at each stage, a continuum of the states of nature and multiple electricity market trading sessions are possible. The model is set in a suitable time uncertainty-information structure in order to capture the evolutionary aspects of the problem in response to an increasing level of information. Uncertainty on future possible stages leads to the problem being located in a filtered probability space. In our analysis, we take the point of view of power generators (companies) that produce electricity with conventional and renewable-based plants. The aim of each agent is to maximize its expected profit function. Moreover, in order to control the risk of profit variability over the given planning horizon, we introduce a suitable risk measure. The problem is studied as a suitable equilibrium problem for the entire market system. The aim is to reformulate it as a suitable stochastic quasi-variational inequality, in order to analyze the equilibrium problem. This is a joint work with Elena De Giuli, Giorgia Oggioni and Domenico Scopelliti.

Minimal solutions of master equations for extended mean field games

Chenchen Mou
City University of Hong Kong

In an extended mean field game the vector field governing the flow of the population can be different from that of the individual player at some mean field equilibrium. This new class strictly includes the standard mean field games. It is well known that, without any monotonicity conditions, mean field games typically contain multiple mean field equilibria and the wellposedness of their corresponding master equations fails. In this paper, a partial order for the set of probability measure flows is proposed to compare different mean field equilibria. The minimal and maximal mean field equilibria under this partial order are constructed and satisfy the flow property. The corresponding value functions, however, are in general discontinuous. We thus introduce a notion of weak-viscosity solutions for the master equation and verify that the value functions are indeed weak-viscosity solutions. Moreover, a comparison principle for weak-viscosity semi-solutions is established and thus these two value

functions serve as the minimal and maximal weak-viscosity solutions in appropriate sense. In particular, when these two value functions coincide, the value function becomes the unique weak-viscosity solution to the master equation. The novelties of the work persist even when restricted to the standard mean field games.
This is a joint work with Jianfeng Zhang.

Real Option Value of Article 11

Aaraona Rakotoarivony
Université Paris Cité

According to the bankruptcy code in the United States, when in financial distress, a company can file for liquidation under Chapter 7 or seek protection under Chapter 11. Under Chapter 11, the referee grants the company an automatic stay during which litigations against the debtors are put on hold. In this paper, we are concerned with the real option value of this opportunity. We frame our problem as one of maximization of dividend emission. The cash process is modeled as a homogeneous diffusion and is allowed to stay a limited amount of time below an exogenous barrier. We solve this problem through the use of viscosity techniques and enrich our study with numerical analysis.
This is a joint work with Vathana Ly Vath and Simone Scotti.

On Projected Solutions for Quasi Equilibrium Problems with Non-self Constraint Map

Maede Ramazannejad
Università Cattolica del Sacro Cuore

In a normed space setting, this paper studies the conditions under which the projected solutions to a quasi equilibrium problem with non-self constraint map exist. Our approach is based on an iterative scheme which gives rise to a sequence weakly converging to a projected solution. Finally, as a particular case, we discuss the existence of projected solutions to a quasi variational inequality problem.
This is a joint work with Monica Bianchi and Enrico Miglierina.

A stochastic bilevel model for assessing the efficiency and sustainability of water supply systems

Rossana Riccardi
Università di Brescia

The aim of this work is to study a regional water market where several water utilities operate: each water utility has the license for managing wells, reservours and wastewater treatment plants that are located in the zones in which the regional market is divided. Water utilities can expand their water capacity by constructing new wells or reservour, can reduce their water losses with new investments in the infrastructures, can increase the percentage of wastewater treated by constructing new wastewater plants. These new investments are rewarded by the water utilities in terms of an increase in the marginal water tariff. All the water utilities maximize their individual profits simultaneously and, as a result, the market may reach an equilibrium; at the same time, a water authority aims to reduce water scarcity, water losses, and untreated water quantities. This behavior can be modeled as a bilevel stochastic programming problem. In the upper-level, the water authority wants to minimize the social cost, that is, the increase in the total cost due to the new investments and the social cost for water scarcity. The upper-level problem is constrained by the water authority's feasible region and by a set representing the equilibrium solutions of the water utilities. Each water utility, indeed, maximizes its own profit, subject to technological constraints. The upper-level and lower-level problems are interrelated since the upper-level problem determines the optimal water marginal tariff curve to submit to the lower-level problem, whereas the lower-level problem sets the water quantities distributed by the different water utilities and the investments decision variables that have a direct effect on the water regulator social cost and on the fulfillment of the target level of efficiency. From a theoretical point of view, the existence of at least one equilibrium for the bilevel problem has been proved. In addition, taking into account that the problem is NP-Hard to be solved, an ad hoc algorithmic procedure has been studied to tackle this problem.
This is a joint work with Elisabetta Allevi; Riccardo Cambini and Domenico Scopelliti.

A Mean Field Game model for COVID-19 with human capital accumulation

Cristiano Ricci
Università di Pisa

In this manuscript, we study a model of human capital accumulation during the spread of a disease following an agent-based approach, where agents behave maximizing their intertemporal utility. We assume that the agent interaction is of mean-field type, yielding a Mean Field Game description of the problem. We discuss how the analysis of a model including both the mechanism of change of species from one epidemiological state to the other and an optimization problem for each agent leads to an aggregate behaviour that is not easy to describe and sometimes exhibits structural issues. Therefore we eventually propose and study numerically a SEIRD model in which the rate of infection depends on the distribution of the population, given exogenously as the solution to the Mean Field Game system arising as the macroscopic description of the discrete multi-agent economic model for the accumulation of human capital. Such a model arises in fact as a simplified but tractable version of the initial one.
This is a joint work with Daria Ghilli and Giovanni Zanco.

Optimal ratcheting dividends policy with resets

Alexandre Roch
Université du Québec à Montreal

We study an optimal dividend problem under ratcheting and bankruptcy constraints. Firms face a tradeoff between the negative signal of a dividend reduction and a potential future bankruptcy. In contrast to previous works, the dividend rate is allowed to decrease after incurring a reputation cost in accordance with a large empirical literature on the topic. We provide an explicit sufficient and necessary condition for the finiteness of the value function and prove the differentiability of the value function, and its characterization via viscosity solutions and the so-called super-contact property. The value function is given by the solution of a two-dimensional PDE combining optimal stopping, singular and impulse controls. We show that the problem is equivalent to a one-dimensional setup simplifying both mathematical and financial analysis. Finally, we detail the numerical study of the model and we provide a sensitivity analysis with respect to the model parameters.
This is a joint work with Simone Scotti.

Single-Leader-Radner-Equilibrium: a new approach for a class of bilevel problems under uncertainty

Domenico Scopelliti
Università di Brescia

Bilevel problems with several followers, often called Single-Leader-Multi-Follower problems, have been proved to be very useful for the modeling hierarchical interactions between agents in Economics, industry, etc. When uncertainty must be taking into account a classical approach is to use stochastic bilevel optimization. In this talk, we introduce an alternative approach intrinsically integrating at the same time uncertain future and time dependent decision processes. It is called Single-Leader-Radner-Equilibrium (SLRE) and is characterized by a hierarchical structure with one leader and several followers competing to reach a Radner equilibrium. A variational reformulation of quasiconcave SLRE model (that is, where the objective function of the followers are only quasiconcave) is proposed and used to prove the existence of optimistic solution of quasiconcave SLRE. Finally, thanks to these developments we present a new approach of optimal design of Eco-Industrial parks.
This is a joint work with Elisabetta Allevi; Didier Aussel and Rossana Riccardi.

Optimal reinsurance via BSDEs in a partially observable model with jump clusters

Carlo Sgarra
Politecnico di Milano

We investigate the optimal reinsurance problem when the loss process exhibits jump clustering features and the insurance company has restricted information about the loss process. We maximize expected exponential utility of terminal wealth and show that an optimal solution exists. By exploiting both the Kushner-Stratonovich and Zakai approaches, we provide the equation governing the dynamics of the (infinite-dimensional) filter and characterize the solution of the stochastic optimization problem in terms of a BSDE, for which we prove existence and uniqueness of solution. After discussing the optimal strategy for a general reinsurance premium, we provide more explicit results in some relevant cases.
This is a joint work with Matteo Brachetta; Giorgia Callegaro and Claudia Ceci.

A mean-field version of Bank-El Karoui's representation of stochastic processes

Xiaolu Tan
The Chinese University of Hong Kong

We study a mean-field version of Bank-El Karoui's representation theorem of stochastic processes. Under different technical conditions, we establish some existence and uniqueness results. As motivation and first applications, our mean-field representation results provide a unified approach to study different Mean-Field Games (MFGs) in the setting with common noise and multiple populations, including the MFG of timing, the MFG with singular control, etc. As a crucial technical step, we provide a stability result on the classical Bank-El Karoui's representation theorem, which has its own interests and other applications, such as in deriving stability results of the optimizers (in the strong sense) for a class of optimal stopping problems and singular control problems.
This is a joint work with Xihao He and Jun Zou.

Adaptive proximal gradient methods for convex bilevel optimization

Andreas Themelis
Kyushu University

Bilevel optimization is a comprehensive framework that bridges single- and multi-objective optimization. It encompassess many general formulations, such as, but not limited to, standard nonlinear programs. This work demonstrates how elementary proximal gradient iterations can be used to solve a wide class of convex bilevel optimization problems without involving subroutines. Compared to and improving upon existing methods, ours (1) can handle a much wider class of problems, including both constraints and nonsmooth terms, (2) does not require strong convexity or Lipschitz smoothness assumptions, and (3) provides a systematic adaptive stepsize selection strategy with no need of function evaluations. A linesearch-free variant is also proposed that eliminates wasteful backtracking trials at the sole expense of cost evaluations.
This is a joint work with Puya Latafat; Panagiotis Patrinos and Silvia Villa.

Mean field game of mutual holding and systemic risk

Nizar Touzi
Ecole Polytechnique

We provide an explicit solution for the mean field game of mutual holding with defaultable agents modeled by absorption at zero. The optimal dynamics are defined by a Mckean-Vlasov SDE with discontinuous diffusion coefficient and non-smooth drift coefficient. We also provide an autonomous characterization of the distribution of defaults.
This is a joint work with Fabrice Djete and Gaoyue Guo.

Incomplete Market Equilibrium with "Catching up with the Joneses" Preferences and Several Heterogeneous Agents

Marko Hans Weber
National University of Singapore

We find closed-form expressions for the general equilibrium of a pure-exchange economy with n heterogeneous agents who receive idiosyncratic unhedgeable income streams, trade a dividend-paying stock, and maximize the expected utility of their consumption relative to a weighted average of other agents' consumption policies. We formulate the limit when the number of agents increases to infinity as a mean field game, and study the equilibrium economy with a continuum of heterogeneous agents.
This is a joint work with Li Mengge and Chao Zhou.

Market Equilibrium under Proportional Transaction Costs in a Stochastic Factor Model

Mihail Zervos

London School of Economics

We consider an economy with two agents. Each of the two agents receives a random endowment flow. We model this cumulative flow as the stochastic integral of a deterministic function of the economy's state, which we model by means of a general Ito diffusion. Each of the two agents has mean-variance preferences with different risk-aversion coefficients. The two agents can also trade a risky asset. We determine the agents' optimal equilibrium trading strategies in the presence of proportional transaction costs. In particular, we derive a new free-boundary problem that provides the solution to the agents' optimal equilibrium problem. Furthermore, we derive the explicit solution to this free-boundary problem when the problem data is such that the frictionless optimiser is a strictly increasing or a strictly increasing and then strictly decreasing function of the economy's state.
This is a joint work with Christoph Czichowsky and Justin Gwee.

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