Stochastics & Computational Finance

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Program & Book of Abstracts

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PROGRAM

All lecture rooms on ISEG, Building Quelhas 6, floors 2 and 4.
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Floor 4: Amphitheater Novo Banco, and Amphitheaters 1, 3 and 4

Tuesday, September 2nd

8:15–9:00	**Registration** – Auditorium Caixa Geral de Depósitos
9:00-9:25	**Opening Session** – Auditorium Caixa Geral de Depósitos
9:30–10:10	**Plenary 1** – Auditorium Caixa Geral de Depósitos (Chair: Ernst Eberlein) **Martin Schweizer:** *Dynamic monotone mean-variance portfolio optimization with independent returns*
10:20–11:00	**Plenary 2** – Auditorium Caixa Geral de Depósitos (Chair: Ernst Eberlein) **Emmanuel Gobet:** *Quantitative modelling of risks in decentralized finance*
11:10–11:35	**Coffee break**
11:35–13:15	**Parallel Sessions 1**

Anphitheater 1 **Minisymposium 1** *Memory in Quantitative Finance I* Chair: Eduardo Abi Jaber	Amphitheater Novo Banco **Thematic Session 1** *Stochastic Models for Sustainability* Chair: Nuno Brites	Amphitheater 3 **Thematic Session 2** *Machine Learning Approaches in Financial Stochastics* Chair: Álvaro Leitao Rodríguez
Sergio Pulido: *Polynomial Volterra processes*	**Sven Karbach:** *Semi-static hedging of volumetric risk in energy markets*	**Jean-Loup Dupret:** *Deep Learning for continuous-time stochastic control with jumps*
Elie Attal: *Simulating affine Volterra processes via inverse Gaussian*	**João Brazão:** *A real option model for harvesting*	**Aleksandar Arandjelovic:** *Algorithmic strategies in continuous-time hedging and stochastic integration*
Christian Bayer: *American option pricing in rough volatility models*	**Rodrigo Graça:** *A Methodological revisit of green bond premium*	**Diogo Franquinho:** *Neural network empowered liquidity pricing in a two-price economy under conic finance settings*
Alessandro Bondi: *Fredholm approach to nonlinear propagator models*	**Lionel Sopgoui:** *Impact of the carbon price on credit portfolio's loss with stochastic collateral*	**Daria Sakhanda:** *Optimal consumption policy in a carbon-conscious economy: a machine learning approach*

13:15–14:30	**Lunch**	Rooftop

14:35-15:15	**Plenary 3** – Auditorium Caixa Geral de Depósitos (Chair: João Guerra) **Roxana Dumitrescu:** *Advances in the linear programming approach for mean-field games and multi-scale MFGs with common noise*
15:25–16:05	**Plenary 4** – Auditorium Caixa Geral de Depósitos (Chair: João Guerra) **Matthias Ehrhardt:** *A novel space mapping approach for the calibration of financial models*
16:15–16:40	**Coffee break**
16:45–18:25	**Parallel Sessions 2**

Amphitheater 1 **Minisymposium 2** *Memory in Quantitative Finance II* Chair: Eduardo Abi Jaber	Amph. Novo Banco **Minisymposium 3** *ECMI SIG: Computational Methods for Finance and Energy Markets I* Chair: Carlos Vázquez	Amphitheater 3 **Minisymposium 4** *Advances on Mean-Field Theory with Applications to Generative AI and Energy Transition* Chair: Roxana Dumitrescu	Amphitheater 4 **Thematic Session 3** *Stochastic models I* Chair: Raquel Gaspar
Eyal Neumann: *Stochastic graphon games with memory*	**Gianluca Fusai:** *Navigating supply shocks: sector resilience and production prices through stochastic input-output modeling*	**Luciano Campi:** *Continuous-time persuasion by filtering*	**Roberto Baviera:** *Is Spearman's ρ a robust measure of correlation for financial time series?*
Léo Parent: *The discrete-time 4-factor PDV model: calibration under $\mathbb{P}$ and $\mathbb{Q}$*	**Yannick Becker:** *Portfolio optimization under return uncertainty: from sensitivity to robustness*	**Quentin Jacquet:** *A rank-based reward between a principal and a field of agents: application to energy savings*	**Pietro Manzoni:** *The role of expert judgement in insurance internal model for operational risk*
Dimitri Sotnikov: *Martingale property and moment explosions in signature volatility models*	**Josha A. Dekker:** *Optimal stopping with randomly arriving opportunities to stop*	**Mehdi Talbi:** *Sannikov's contracting problem with many agents*	**Vesna Rajić:** *Application of generalized linear models in assessing the influence of acquisition costs on insurance premiums*
Eduardo Abi Jaber: *Signature approach for path dependent hedging with frictions*	**Edouard Motte:** *The Volterra Stein-Stein model with stochastic interest rates*	**Yufei Zhang:** *Continuous-time mean field games: a primal-dual characterization*	**Pavel Gapeev:** *Bayesian quickest double disorder detection problems with linear delay penalty*

Wednesday, September 3rd

9:00–9:40	**Plenary 5** – Auditorium Caixa Geral de Depósitos (Chair: Laura Ballotta) **Bruno Dupire:** *Some financial applications of the functional Itô calculus*
9:50–11:00	Auditorium Caixa Geral de Depósitos: **Celebration in honour of Prof. Albert Shiryaev** (Chair: Martin Schweizer) **Plenary 6 –** **Albert Shiryaev:** *On parameter estimation of diffusion processes by maximum likelihood method*
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Oliver Rúas-Barrosa: *Power purchase agreements: a renewable energy approach*	**Yating Liu:** *Supervised classification for interacting particles*	**Hugo Ramirez:** *Benchmarking of index funds with transaction costs*
Bianca Moreno: *Online convex reinforcement learning and applications to energy management problems*	**Loïc Béthencourt:** *Brownian particles controlled by their occupation measure*	**Javier Garcia:** *Daily leverage and long-term investing using leveraged exchange traded funds*
Jörg Müller: *Oil as a spoilsport in ESG investing? An analysis of the correlation effects of stocks in the ESG spectrum*	**Armand Bernou:** *Convex order for the McKean-Vlasov equation with common noise and applications*	**Amal Omrani:** *Beyond the Leland strategies*
	Ying Jiao: *An efficient shared socioeconomic pathways based methodology for assessing climate risks of a large credit portfolio*	

13:15–14:30	**Lunch** Rooftop
14:35–15:15	**Plenary 7** – Auditorium Caixa Geral de Depósitos (Chair: Carlos Vázquez) **Nizar Touzi:** *Model risk hedging and path-dependent distributionally robust control*
15:25–16:05	**Plenary 8** – Auditorium Caixa Geral de Depósitos (Chair: Carlos Vázquez) **Peter Tankov:** *Climate risks, tipping points and emission reduction*
16:15-16:40	**Coffee break**

16:45-18:25 **Parallel Sessions 4**

Amphitheatre Novo Banco	Amphitheatre 1	Amphitheatre 3
Minisymposium 7 *ECMI SIG: Computational Methods for Finance and Energy Markets III* Chair: Matthias Ehrhardt	**Minisymposium 8** *Time-inhomogeneous Lévy (additive) processes: applications in finance and energy* Chair: Michele Azzone	**Thematic Session 5** *Stochastic Models II* Chair: Carlos Oliveira
Michael Günther: *Port-Hamiltonian systems in quantitative finance*	**Michele Azzone:** *Additive normal tempered stable processes and additive subordination for equity derivatives*	**Maxime Guellil:** *Fourier-Laplace transform discontinuities and computation in the Volterra Stein-Stein model: a Fredholm-Wishart approach*
Álvaro Leitao Rodríguez: *Deep joint learning valuation of Bermudan swaptions*	**Laura Ballotta:** *Multivariate additive subordination with applications in finance*	**Gonçalo dos Reis:** *Simulation of mean-field SDEs: some recent results*
Jing Wang: *Controllable generation of implied volatility surfaces with variational autoencoders*	**Guixin Liu:** *Neural term structure of additive process for option pricing*	**Miguel Reis:** *Stochastic differential equations harvesting models: simulation and numerical solution*
Ray Wu: *Efficient high-order smoothing methods for rainbow options on sparse grids*	**Marco Vitelli:** *Overcoming misconceptions about local volatility: exact prices lead to sound continuous Markovian models*	**Mohamed El-Beltagy:** *Basis development of the fractional Wiener chaos expansions for the analysis of stochastic models driven by fractional Brownian motion*

Thursday, September 4th

9:00–9:40	**Plenary 9** – Auditorium Caixa Geral de Depósitos (Chair: Matthias Ehrhardt) **Carlos Vázquez:** *Some recent advances in the pricing of renewable energy certificates and some derivatives*
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11:35–13:15	**Parallel Sessions 5**

Amph. Novo Banco	Amphitheatre 1	Amphitheatre 3	Amphitheatre 4
Minisymposium 9 *Advanced Pricing Models and Numerical Approaches for Emission Allowances and Renewable Energy Certificates* Chair: J.-F. Chassagneux	**Minisymposium 10** *Risk Management for Financial and Real Assets* Chair: Ana Monteiro	**Minisymposium 11** *Machine Learning and Information Geometry in Finance* Chair: Amine Aboussalah	**Thematic Session 6** *Mean Field Games, Stochastic Control and Portfolio Optimization II* Chair: Manuel Guerra
Stéphane Crépey: *Sensitivity Analysis of Emissions markets: a discrete-time Radner equilibrium approach*	**Pedro Godinho:** *Regression-based estimation of state-dependent volatility in project simulation models*	**Leonard Wong:** *Macroscopic properties of equity markets: stylized facts and portfolio*	**Josha Dekker:** *Stochastic optimal control with randomly arriving control moments*
Liam Welsh: *Modelling equilibrium behaviour in solar REC and offset credit markets*	**Nuno Silva:** *Using adaptive LASSO to improve portfolio strategies*	**Abderrahmane Abbou:** *Dynamic intervention policy for financially distressed firms with noisy returns*	**Tao Pang:** *Optimal portfolio choice with comfortable consumption*
Yassin El-Hatri: *Modelling the role of hedgers and speculators*	**Ana Monteiro:** *Estimating default intensity using credit default swap (CDS) data*	**Amine Aboussalah:** *Robust financial modeling: A principled framework for generative data augmentation*	**Christoph Czichowsky:** *Duality theory for utility maximisation in Volterra kernel models for transient price impact*

	António Santos: *Hamiltonian Monte Carlo simulations to estimate extended stochastic volatility models within a time-deformed intraday framework*		**Sturmius Tuschmann:** *Stochastic graphon games with memory*
13:15–14:30	**Lunch**		Rooftop
14:35–15:15	**Plenary 11** – Auditorium Caixa Geral de Depósitos (Chair: Daniel Ševčovič) **Jean-François Chassagneux:** *An optimal transport approach to multiple quantile hedging problems*		
15:20-15:45	**Coffee break**		
16:00	**Walk from ISEG to Cais da Rocha de Conde de Óbidos** (20 min)		
16:45–19:00	**Scenic 2-hour Tagus River cruise**		
19:45	**Conference dinner**		

Friday, September 5th

9:00–09:40	**Plenary 12** – Auditorium Caixa Geral de Depósitos (Chair: João Janela) **Peter Spreij:** *Polynomial approximation of discounted moments*
9:50–10:30	**Plenary 13** – Auditorium Caixa Geral de Depósitos (Chair: João Janela) **Daniel Ševčovič:** *Partial Integro-differential equations and their applications in financial modeling*
10:40–11:05	**Coffee break**
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Minisymposium 12 *Recent approaches to Portfolio Optimization, Interest Rate Determination, Option Pricing and Intensity Graduation in Multiple State Models* Chair: Manuel L. Esquível	**Thematic Session 7** *Stochastic models III* Chair: Gonçalo dos Reis	**Thematic Session 8** *Portfolio Management, Insurance and Investments* Chair: Alexandra Moura
Marta Faias: *Measuring the impact of socially responsible investments on portfolio performance using the Shapley value*	**Josep Vives:** *Computation of Greeks under rough Volterra stochastic volatility models using Malliavin calculus*	**Martin Arnaiz:** *A stochastic mirror descent algorithm for risk budgeting portfolios*
Raquel Gaspar: *Option pricing: quality versus quantity in the era of Big Data*	**Lilian Hu:** *New perspectives on analytic solvability of stochastic volatility models*	**Alessandro Staino:** *Minimum capital requirement for non-life insurance with risk budgeting portfolios*
Gracinda Guerreiro: *Risk-adjusted estimation and graduation of transition intensities for disability and long-term care insurance: a multi-state model approach*	**Carlos Glória:** *Robust equilibrium asset and option pricing*	**Jelena Stanojević:** *Assessing the efficiency of insurance companies using fuzzy data envelopment analysis: evidence from Serbia*
Manuel L. Esquível: *On model improvement algorithms: an application to interest rates determination*	**Miloš Božović:** *Intraday jumps and 0DTE options: pricing and hedging implications*	**Dragana Radojicić:** *Benford's law: distributional properties, simulations, and real-world conformity tests*

12:50–13:15	**Closing Session** – Auditorium Caixa Geral de Depósitos	
13:15-14:30	**Lunch and Port Wine Farewell**	Rooftop

ABSTRACTS

PLENARY SPEAKERS

An optimal transport approach to multiple quantile hedging problems

Jean-François Chassagneux[1,*], C. Bénézet[2], M. Yang[3]

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[2] ENSIIE
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Abstract

In this talk, I will introduce a class of 'weak hedging problem' which contains as special examples the quantile hedging problem (Föllmer Leukert 1999) and Profit and Loss matching problem (introduced in Bouchard & Vu 2012).I will present quickly the 'classical' approach to solve the quantile hedging problem. Then, I will then show how they can generally be rewritten as a kind of Monge transport problem. Using this observation, we introduce a Kantorovich version of the problem and, in the linear case, we are able to prove a dual formulation. It allows us in particular to design numerical methods based on SGA algorithms to compute the weak hedging price.

Advances in the linear programming approach for mean-field games and multi-scale MFGs with common noise

Roxana Dumitrescu[1,*]

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Abstract

The linear programming (LP) approach provides a recently introduced alternative for studying mean-field games (MFGs), complementing existing methods like the partial differential equation (PDE) framework developed by Lasry and Lions, and the probabilistic approach of Carmona and Delarue. This formulation not only simplifies existence proofs but also facilitates the development of efficient numerical algorithms. By recasting the stochastic control problems underlying MFGs as infinite-dimensional linear programming problems, this method is particularly useful in settings involving optimal stopping and singular control, where the lack of regularity in the flow of measures poses significant challenges for PDE-based techniques.

In the first part of the talk, I will provide a brief overview of the linear programming approach to MFGs and recent results related to its connection with randomized stopping. In the second part, I will present new developments in the study of multi-scale mean-field games with common noise, where the LP approach serves as a key tool.

Some financial applications of the functional Itô calculus

Bruno Dupire[1,2,*]

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Abstract

Path dependence is ubiquitous in finance, sometimes explicitly as the payoff of an exotic option may depend on the whole path of the asset price, not only at maturity, other times through the dynamics of the underlying (volatility, dividends. . .).

The framework to model path dependence is the Functional Itô Calculus and we review its basic concepts before offering a partial panorama of its applications: computation of the Greeks of path dependent options, perturbation analysis, volatility risk decomposition, Taylor expansion with signatures for fast computation of VaR and characterization of attainable claims, amongst other ones.

The term structure of implied correlations between S&P and VIX markets

Laura Ballotta[1], Ernst Eberlein[2,*], Grégory Rayée[3]

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Abstract

We develop a joint model for the S&P500 and the VIX indices with the aim of extracting forward looking information on the correlation between the two markets. We achieve this by building the model on time changed Lévy processes, deriving closed analytical expressions for relevant quantities directly from the joint characteristic function, and exploiting the market quotes of options on both indices. We perform a piecewise joint calibration to the option prices to ensure the highest level of precision within the limits of the availability of quotes in the dataset and their liquidity. Using the calibrated parameters, we are able to quantify the leverage effect along the term structure of the VIX options and corresponding VIX futures. We illustrate the model using market data on S&P500 options and both futures and options on the VIX.

Keywords: Lévy processes, Time changes, Implied correlation, Option pricing

A novel space mapping approach for the calibration of financial models

Matthias Ehrhardt[1,*], Anna Clevenhaus[1], Claudia Totzeck[2]

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Abstract

In this talk we present a novel approach for parameter calibration of the Heston model for pricing an Asian put option, namely space mapping. Since few parameters of the Heston model can be directly extracted from real market data, calibration to real market data is implicit and therefore a challenging task. In addition, some of the parameters in the model are non-linear, which makes it difficult to find the global minimum of the optimization problem within the calibration. Our approach is based on the idea of space mapping, exploiting the residuum of a coarse surrogate model that allows optimization and a fine model that needs to be calibrated. In our case, the pricing of an Asian option using the Heston model SDE is the fine model, and the surrogate is chosen to be the Heston model PDE pricing a European option. We formally derive a gradient descent algorithm for the PDE constrained calibration model using well-known techniques from optimization with PDEs. Our main goal is to provide evidence that the space mapping approach can be useful in financial calibration tasks. Numerical results underline the feasibility of our approach.

Quantitative modelling of risks in decentralized finance

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Abstract

I will examine emerging quantitative challenges in Decentralized Finance (DeFi), with a focus on the mechanisms of Automated Market Makers (AMMs), lending and borrowing protocols, price discovery processes, and arbitrage dynamics between centralized and decentralized exchanges (CEXs and DEXs). I will also present associated modeling approaches and discuss the theoretical and practical questions they entail.

Dynamic monotone mean-variance portfolio optimisation with independent returns

Martin Schweizer[1,*], Aleš Černý[2], Johannes Ruf[3]
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Abstract

Mean–variance portfolio choice, while popular, has some serious drawbacks: it can lead to time-inconsistent problems, and it is not monotone. We consider instead its modification to monotone mean–variance (MMV), and we want to find a dynamic portfolio strategy which maximises the MMV criterion for final wealth on a finite horizon. Assuming only that the underlying semimartingale asset price model has independent returns, we are able to provide a complete and explicit solution. The only assumption we need is a weak local absence-of-arbitrage condition, and we can show that our results are sharp.

Keywords: Portfolio optimisation, Monotone mean–variance, Independent returns.

Partial integro-differential equations and their applications in financial modeling

Daniel Ševčovič[1,*], J. Cruz[2], Cyril I. Udeani[1]
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Abstract

In this presentation, we analyze solutions of a non-local nonlinear partial integro-differential equation (PIDE) in multidimensional spaces. Such a class of PIDE often arises in financial modeling. We employ the theory of abstract semilinear parabolic equations in order to prove the existence and uniqueness of solutions on the scale of Bessel potential spaces. We consider a wide class of Lévy measures satisfying suitable growth conditions near the origin and infinity. The novelty of the paper is 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 Lévy stochastic process with jumps. As an application to option pricing in the one-dimensional space, we consider a general shift function arising from nonlinear option pricing models taking into account a large trader stock-trading strategy. We prove the 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. This is based on papers [1], [2], [3] and [4].

Keywords: Lévy measure, Option pricing, Strong kernel; Hölder continuity, Partial integro-differential equation, Bessel potential spaces.

References

[1] Cruz J., Ševčovič D. "On solutions of a partial integro-differential Black-Scholes equation in Bessel potential spaces." Japan Journal of Industrial and Applied Mathematics 37, 691–721 (2020).

[2] Cruz J., Ševčovič D. "Option Pricing in Illiquid Markets with Jumps." Applied Mathematical Finance, 25(4), 389–409 (2018).

[3] Ševčovič D., Udeani C.I. "Application of maximal monotone operator method for solving Hamilton-Jacobi-Bellman equation arising from optimal portfolio selection problem." Japan Journal of Industrial and Applied Mathematics, 38(3), 693–713 (2021).

[4] Ševčovič D., Udeani, C.I. "Multidimensional linear and nonlinear partial integro-differential equation in Bessel potential spaces with applications in option pricing." Mathematics, 9(13), 1463 (2020).

On parameter estimation of diffusion processes by maximum likelihood method

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[2]University of Technology, Sydney, Australia
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Abstract

We make a revision of some old results and give new one for the problem of estimation of parameter L by observation process X on stochastic intervals. Process X satisfies to stochastic differential equation governed by Brown motion and drift terms $F(t, L, X)$ and volatility $D(t, X)$. Special attention will be done for models OU and CIR by analytical and numerical methods.

Polynomial approximation of discounted moments

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Abstract

We introduce an approximation strategy for the discounted moments of a stochastic process that can, for a large class of problems, approximate the true moments. These moments appear in pricing formulas of financial products such as bonds and credit derivatives. The approximation relies on high-order power series expansion of the infinitesimal generator, and draws parallels with the theory of polynomial processes. We demonstrate applications to bond pricing and credit derivatives. In the special cases that allow for an analytical solution the approximation error decreases to around 10 to 100 times machine precision for higher orders. When no analytical solution exists we tie out the approximation with existing numerical techniques.

Keywords: Markov processes, Credit models, Generator, Resolvent

References

[1] Zhao C., van Beek M., Spreij P., Ba M. "Polynomial approximation of discounted moments." Finance and Stochastics 29, 63–95 (2025).

Climate risks, tipping points and emission reduction

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Abstract

We develop a simple model of optimal emission reduction in the presence of climate tipping points, where the remaining carbon budget before reaching a tipping point is uncertain, and the detection of its occurrence is subject to measurement noise. Assuming that agents are reluctant to reduce emissions before the tipping point occurs, but are averse to the physical climate risks that will materialize afterward, we formulate the optimal emission reduction problem as an optimal switching problem under partial information. We then characterize the optimal strategies as a function of the remaining carbon budget and the perceived likelihood of crossing a tipping threshold. Our results show that the optimal emission reduction trajectory does not follow a smooth path, but instead consists of alternating periods of strong and weak climate policy, depending on the public perception of the catastrophic risks associated with tipping points.

Keywords: Climate risks, Climate tipping points, Optimal emission reduction, Optimal switching, Partial information

Model risk hedging and path-dependent distributionally robust control

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Abstract

Distributionally robust optimization (DRO) studies the worst deviation of an evaluation functional on the Wasserstein ball centered at the model of interest. We derive explicit sensitivity analysis under marginal and martingale constraints which provide first order semi-static hedge against model risk. We finally provide some recent extension to distributionally robust control on the paths space.

Some recent advances in the pricing of renewable energy certificates and some derivatives

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Abstract

Renewable Energy Certificates (RECs) or green bonds are used to foster the development of renewable energies to obtain electricity. More precisely, the generators of electricity from renewables receive one certificate per a certain amount of electricity produced, which is refered to as REC. These RECs can be traded and their pricing present some similarities and differences with cap and trade schemes for carbon emissions.

In this talk, some pricing methods for RECs and associated derivatives products are presented. For this purpose, starting from a system of forward-backward differential equations (FBSDEs), we first propose a mathematical model based on a semilinear partial differential equation (PDE) arising from the consideration of two stochastic underlying 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. A set of numerical methods will be proposed and a real case numerical example will be presented.

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. Thus, we derive the 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.

Also some recent extension of the setting will be presented.

CONTRIBUTED TALKS

Dynamic intervention policy for financially distressed firms with noisy returns

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Abstract

We consider the problem of optimally allocating limited financial advisors to multiple firms, each subject to a randomly occurring distress necessitating an advisor's intervention. The problem is formulated as a restless bandit problem in which the state of each firm is the posterior probability of distress occurrence recursively updated from noisy returns data. Through Lagrangian relaxation coupled with a novel stochastic analysis, we derive a mathematical expression for the Whittle index, which is used to assign financial advisors to seemingly distressed firms via the index policy. Moreover, we devise an efficient algorithm to compute a performance bound against which the optimality gap of the index policy can be assessed. Numerical results based on simulated data demonstrate the near optimal performance of the proposed index policy.

Keywords: Restless bandits, Financial distress, Resource allocation

Signature approach for path-dependent hedging with frictions

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Abstract

We show how signatures can be used to hedge path-dependent claims under market frictions.

Robust financial modeling: A principled framework for generative data augmentation

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Abstract

Effective machine learning for financial modeling is often challenged by limited data, leading to overfitting and poor out-of-distribution generalization. This talk introduces a principled framework for data augmentation to address these critical challenges. This framework models diverse data structures, from time series to graph-structured networks. We establish a theoretical foundation for our framework using Rademacher complexity to offer a regret bound on the generalization error, thereby guaranteeing performance under specific conditions. Through empirical evaluation on diverse datasets, we demonstrate that our approach not only significantly outperforms state-of-the-art augmentation techniques but also offers superior computational efficiency. This research provides a robust, theoretically-grounded solution for enhancing the performance and reliability of generative AI models in real-world applications such as finance.

Algorithmic strategies in continuous-time hedging and stochastic integration

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Abstract

We develop a rigorous framework for continuous-time algorithmic trading strategies from the point of view of mathematical finance. To this end, we first establish a universal approximation theorem for neural networks on locally convex spaces with respect to topologies in Orlicz spaces. When the underlying sigma-algebra is generated by an (uncountable) family of random variables, we prove that neural networks - through functional representations - can approximate functions in these Orlicz spaces arbitrarily well. Our main result then represents algorithmic strategies as simple predictable processes to establish their approximation capabilities in spaces of stochastic (integral) processes. As applications, we prove that algorithmic strategies can approximate mean-variance optimal hedging strategies arbitrarily well, and we establish a no free lunch with vanishing risk condition for algorithmic strategies.

Keywords: Deep learning, Universal approximation, Algorithmic strategy, Stochastic integration, Mean-variance hedging, No free lunch with vanishing risk

A stochastic mirror descent algorithm for risk budgeting portfolios

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Abstract

This paper introduces and examines numerical approximation schemes for computing risk budgeting portfolios associated with positive homogeneous and sub-additive risk measures. Rooted in the alternative portfolio construction paradigm proposed in [2], risk budgeting offers a diversification-based approach that avoids reliance on unstable return estimates - a key weakness of classical mean-variance methods, as noted in [3]. We employ Mirror Descent (MD) algorithms to determine the optimal risk budgeting weights in both deterministic and stochastic settings, establishing convergence along with an explicit non-asymptotic quantitative rate for the averaged algorithm. By introducing a tamed gradient, we circumvent the issue of unbounded derivatives near the boundary of the domain, allowing us to derive almost sure convergence guarantees. A comprehensive numerical analysis follows, illustrating our theoretical findings across various risk measures - including standard deviation, Expected Shortfall, deviation measures, and Variantiles - and comparing the performance with that of the projected stochastic gradient descent method recently proposed in [1].

Keywords: Portfolio management, Risk management, Risk measures

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Simulating affine Volterra processes via inverse Gaussian

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Abstract

We propose a robust approximation of Volterra equations, using only integrated kernel quantities, leading to Inverse Gaussian proxies for the law of integrated Affine Volterra processes. This naturally leads to new simple simulation schemes for such processes. The schemes preserve positivity, and can be shown to converge weakly by rewriting them as Affine Volterra equations with a measure-valued kernel. Our method applies to two important examples: Volterra square-root and Hawkes processes. In the first case, when using a fractional kernel, the scheme seems to be more performant as the Hurst index H decreases to -1/2. In the second case, our scheme converges for a wide class of kernels, including explosive or non-decreasing ones. Moreover, it offers an interesting compromise between computational cost and precision, which is not available with the classical simulation schemes for Hawkes processes.

Additive normal tempered stable processes and additive subordination for equity derivatives

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Abstract

We introduce a simple additive process for equity index derivatives that we call the ATS. The model generalizes Lévy Normal Tempered Stable processes (e.g. NIG and VG) with time-dependent parameters. It accurately fits the equity index volatility surfaces in the whole time range of quoted instruments, including options with small time-horizon (days) and long time-horizon (years). We notice that the sub-class of additive processes that can be obtained with an independent additive subordination is incompatible with market data and shows significantly worse calibration performances than the ATS, especially on short time maturities. These results have been observed every business day in a semester on a dataset of S&P 500 and EURO STOXX 50 options.

Keywords: Additive process, Equity volatility, Subordination, Jump processes

Multivariate additive subordination with applications in finance

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Abstract

We introduce a tractable multivariate pure jump process in which the trading time is described by an additive subordinator. The multivariate process retains the additivity property, and therefore is time inhomogeneous, i.e., its increments are independent but nonstationary. We provide the theoretical framework of our process, perform a sensitivity analysis with respect to the time inhomogeneity parameters, and design a Monte Carlo scheme to simulate the trajectories of the process. We then employ the model in the context of option pricing in the FX market. We take advantage of the specific features of currency triangles to extract the joint dynamics of FX log-rates. Extensive tests based on observed market data show that our model outperforms well established pure jump benchmarks.

Keywords: Additive process, Forex markets, Subordination, Jump processes

Is Spearman's ρ a robust measure of correlation for financial time series?

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Abstract

Spearman's ρ is a widely used non-parametric measure of statistical dependence between two time series. Since it is rank-based, it is considered robust, as it is less sensitive to extreme values and therefore relatively resistant to outliers. We prove that when applied to

financial time series with a signi

cant number of zeros, Spearman's ρ can produce widely varying correlation estimates. In such cases,

financially equivalent time series – those that should theoretically exhibit similar dependence – can record highly different Spearman's correlation. We perform an experimental analysis using data from the Global Operational Risk (ORX) dataset, the world's largest operational risk loss dataset. We show that the presence of zeros leads to systematic distortions in Spearman's ρ, making it unreliable for operational risk assessment.

Keywords: Spearman correlation, Operational risk, ORX

American option pricing in rough volatility models

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Abstract

Rough volatility models form an important class of models of stock prices, providing excellent fits to implied volatility surfaces as well as observed price and realized vari- ance time series. However, due to the roughness of volatility trajectories and lack of Markov property, they pose continuing challenges for theoretical and numerical analysis. In this talk, we address the problem of pricing American options, i.e., the optimal stopping problem. We show that classical primal and dual approximation methods for Markovian models can be extended to rough volatility models using the path signature as a feature transformation. We also discuss issues of hyper parameter optimization, optimal use of information, and time discretization.

Portfolio optimization under return uncertainty: from sensitivity to robustness

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Abstract

In portfolio optimization, financial decision-makers face challenges due to uncertain asset properties. For example, expected returns can be subject to market fluctuations. This talk addresses how classical mean-variance frameworks, while widely used, exhibit high sensitivity to input assumptions - particularly expected returns - often resulting in suboptimal or unstable allocations.

First, we present a sensitivity analysis of Markowitz's mean-variance model [1] under *a posteriori* return uncertainty: In a collaboration with a major German insurance company, we assess how variations in asset returns impact the efficiency of selected portfolios. Second, we propose a robust optimization approach that incorporates *in actu* return uncertainty during decision-making. Using benchmark-based regret minimization [2], we formulate tractable robust counterparts, enabling efficient portfolio selection even under uncertain return conditions.

In a previous work [3] on bi-objective mean-variance optimization, we considered variance uncertainty. This contribution instead addresses return uncertainty, reflecting a key insight from practice: modeling returns is often prioritized over modeling variance. The proposed methods contribute computationally efficient tools to enhance portfolio robustness in uncertain and data-driven financial market contexts.

Keywords: Portfolio optimization, Uncertainty, Sensitivity, Robustness

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Convex order for the McKean-Vlasov equation with common noise and applications

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Abstract

We establish results on the conditional and standard convex order, as well as the increasing convex order, for two solutions of the McKean-Vlasov equations with common Brownian noise. Similar convex order results are also established for the corresponding particle system. We explore applications of these results to stochastic control problems?deducing in particular an associated comparison principle for Hamilton-Jacobi-Bellman equations with different coefficients and to the interbank systemic risk model introduced by Carmona, Fouque, and Sun.

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Brownian particles controlled by their occupation measure

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Abstract

Originally motivated by the modelling of the growth of mycellium, we study a finite horizon linear-quadratic stochastic optimal control problem for particles, where the cost functions depend on the state and the occupation measure of the the particles. I will explain how to adress this problem by establishing an Itô formula for the flow of occupation measures, which enables us to derive a Feynman-Kac formula, from which we are then able to solve the Hamilton-Jacobi-Bellman equation associated to the control problem. This is a non-linear PDE on the space of measures and the state space. Finally, we construct an optimal control and an optimal trajectory. This work may have several applications in finance.

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Short-lived gases, carbon markets and climate risk mitigation

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Abstract

We study the problem of optimal climate risk mitigation with short-term emission reduction targets and long-run temperature stabilization goals in the presence of firms generating greenhouse gases with different temporal persistency and warming potential. We investigate how the pervasive notion of carbon equivalence may undermine climate risk mitigation efforts when carbon markets can be used to trade short-lived gasses against long-lived ones. The findings are used to demonstrate the vulnerability of certain emission metrics and carbon accounting standards to greenwashing and to support the reporting of emissions in disaggregated form and native units of measure.

Keywords: Compliance carbon markets, Short lived gases, Optimal climate regulation

Fredholm approach to nonlinear propagator models

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Abstract

We formulate and solve an optimal trading problem with alpha signals, where trans- actions induce a nonlinear transient price impact described by a general propagator model, including a power-law decay. Using a variational approach, we demonstrate that the optimal trading strategy satisfies a nonlinear stochastic Fredholm equation with both forward and backward coefficients. We prove the existence and unique- ness of the solution under a monotonicity condition reflecting the nonlinearity of the price impact. Moreover, we derive an existence result for the optimal strategy beyond this condition when the underlying probability space is countable. We intro- duce a novel iterative scheme and establish its convergence to the optimal trading strategy. We also provide a numerical implementation of the scheme that illustrates its convergence, stability, and the effects of concavity on optimal execution strate- gies under exponential and power-law decays.

Intraday jumps and 0DTE options: Pricing and hedging implications

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Abstract

Trading in zero-days-to-expiry (0DTE) options has exploded in popularity over the last few years, surpassing half of all SPX options volume [1]. Despite the recent surge in trading volumes, the literature on 0DTEs is relatively scarce. Existing research in option pricing barely considered specifics of ultra-short-dated options, with a notable exception of some recent working papers [2]–[7].

In this paper, I examine the impact of intraday jumps on the pricing of ultra-short-term options and the associated hedging strategies. I use a continuous-time stochastic volatility model with Poisson jumps and derive semi-closed-form expressions for European option prices to assess market-implied risk premia for return diffusion, volatility and jump risks. I infer the model parameters by applying the Efficient Method of Moments proposed by Gallant and Tauchen [8] on the 9,164 SPX five-minute bars. I use the diurnal adjustment from the Autoregressive Conditional Duration model of Engle and Russell [9] to represent diurnal patterns in intraday data.

I show that intraday jumps in the underlying index are significant in frequency and size. Jump intensity tends to cluster near the market opening and closing hours, exhibiting a stronger pattern than diurnal volatility. Furthermore, using a sample of 22,410 five-minute observations of SPXW options with the same-day expiry, I find that jump risk premia are significant and almost double in magnitude than the combined premium for return diffusion and volatility risks. I employ these results to argue that the 0DTEs represent a natural hedge against extreme intraday movements in the market.

Keywords: Ultra short-dated options, Diurnal patterns, Jump risk premium, Extreme price movements, Event-based trading

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A real option model for harvesting

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Abstract

Harvesting from natural resources, particularly fisheries, has played a central role in supporting human society, both as a source of food and economic activity. Decisions related to harvesting are influenced not only by biological and environmental conditions but also by economic incentives. Understanding how to manage these resources sustainably is essential for balancing short-term gains with long-term viability.

Despite its importance, the fishing industry faces significant challenges. When fishing efforts exceed ecological limits, fish stocks can collapse due to direct human impact. In contexts where access to fishing grounds is open or poorly regulated, excessive effort can be applied simultaneously by many players, placing unsustainable pressure on the resource.

To better manage this uncertainty and irreversibility of the investment, the decision to harvest can be framed as a real option (see [1]). This approach treats the opportunity to fish as a right, not an obligation, allowing fishermen to delay harvesting until conditions are favourable.

We formulate the optimal harvesting policy as a stochastic control problem, leading to a Hamilton-Jacobi-Bellman (HJB) partial differential equation (PDE), as in [2]. Following [3], we solve the HJB equation numerically, allowing us to simulate and analyse optimal policies under various scenarios. The results contribute to a better understanding of sustainable exploitation and highlight the economic value of flexibility in fisheries management.

Keywords: Stochastic differential equations, Partial differential equations, Real options, Harvesting option, Hamilton-Jacobi-Bellman equation, Crank-Nicholson scheme, Numerical methods

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Continuous-time persuasion by filtering

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Abstract

We frame dynamic persuasion in a partial observation stochastic control Leader-Follower game with an ergodic criterion. The Receiver controls the dynamics of a multidimensional unobserved state process. Information is provided to the Receiver through a device designed by the Sender that generates the observation process. The commitment of the Sender is enforced. We develop this approach in the case where all dynamics are linear and the preferences of the Receiver are linear-quadratic. We prove a verification theorem for the existence and uniqueness of the solution of the HJB equation satisfied by the Receiver's value function. An extension to the case of persuasion of a mean field of interacting Receivers is also provided. We illustrate this approach in two applications: the provision of information to electricity consumers with a smart meter designed by an electricity producer; the information provided by carbon footprint accounting rules to companies engaged in a best-in-class emissions reduction effort. In the first application, we link the benefits of information provision to the mispricing of electricity production. In the latter, we show that even in the absence of information cost, it might be optimal for the regulator to blur information available to firms to prevent them from coordinating on a higher level of carbon footprint to reduce their cost of reaching a below average emission target.

Sensitivity analysis of emissions markets: a discrete-time Radner equilibrium approach

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Abstract

Emissions markets play a crucial role in reducing pollution by encouraging firms to minimize costs. However, their structure heavily relies on the decisions of policymakers, on the future economic activities, and on the availability of abatement technologies. This study examines how changes in regulatory standards, firms' abatement costs, and emissions levels affect allowance prices and firms' efforts to reduce emissions. This is done in a Radner equilibrium framework encompassing inter-temporal decision-making, uncertainty, and a comprehensive assessment of the market dynamics and outcomes.

Keywords: Emissions, Carbon market, Radner equilibrium, Sensitivity analysis

Duality theory for utility maximisation in Volterra kernel models for transient price impact

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Abstract

Incorporating the impact of past trades on future prices is crucial to understand the profitability of trading strategies. Recently, Volterra kernels have been proposed as tractable models to capture this transient feature of price impact in optimal execution problems. In this talk, we consider expected utility maximisation in such propagator models for transient price impact. We solve this problem by convex duality and establishing the solution to a suitable dual problem. For this, we identify an appropriate class of dual variables and develop a novel super-replication theorem. Despite the infinite dimensionality of the state variables of the optimal control problem, our approach allows us to recover the tractability of linear-quadratic optimal execution problems for the non-linear-quadratic utility maximisation problem. The talk is based on joint work with Jun Cheng.

Keywords: Duality theory, Portfolio optimisation, Price impact models, Volterra stochastic optimal control

Optimal stopping with randomly arriving opportunities to stop

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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 and a martingale based duality result.

To numerically solve this problem, we design random times versions of the least-squares Monte-Carlo, Andersen-Broadie and policy iteration methods. We illustrate the efficiency of our methods and the relevance of randomly arriving opportunities in a few examples.

Keywords: Optimal stopping, Limited liquidity

Stochastic optimal control with randomly arriving control moments

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Abstract

Control problems with randomly arriving control moments occur naturally. Financial situations in which control moments may arrive randomly are e.g., asset-liquidity spirals or optimal hedging in illiquid markets. We develop methods and algorithms to analyze such problems in a continuous time finite horizon setting, under mild conditions on the arrival process of control moments.

Operating on the random timescale implied by the control moments, we obtain a discrete time, infinite-horizon problem. This problem may be solved accordingly or suitably truncated to a finite-horizon problem. We develop a stochastic primal-dual simulation-and-regression algorithm that does not require knowledge of the transition probabilities, as these may not be readily available for such problems. To this end, we present a corresponding dual representation result.

We then apply our methods to several examples, where we explore in particular the effect of randomly arriving control moments on the optimal control policies.

Keywords: Stochastic optimal control, Hedging under constraints, Limited liquidity

Simulation of mean-field SDEs: some recent results

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Abstract

We review two results in the simulation for SDE of McKean-Vlasov type (MV-SDE). The first block of results addresses simulation of MVSDEs having super-linear growth in the spatial and the interaction component in the drift, and non-constant Lipschitz diffusion coefficient. The 2nd block is far more curious. It addresses the study the weak convergence behaviour of the Leimkuhler–Matthews method, a non-Markovian Euler–type scheme with the same computational cost as the Euler scheme, for the approximation of the stationary distribution of a one-dimensional McKean–Vlasov Stochastic Differential Equation (MV-SDE). The particular class under study is known as mean-field (overdamped) Langevin equations (MFL).We provide weak and strong error results for the scheme in both finite and infinite time. We work under a strong convexity assumption. Based on a careful analysis of the variation processes and the Kolmogorov backward equation for the particle system associated with the MV-SDE, we show that the method attains a higher-order approximation accuracy in the long-time limit (of weak order convergence rate 3/2) than the standard Euler method (of weak order 1). While we use an interacting particle system (IPS) to approximate the MV-SDE, we show the convergence rate is independent of the dimension of the IPS and this includes establishing uniform-in-time decay estimates for moments of the IPS, the Kolmogorov backward equation and their derivatives. The theoretical findings are supported by numerical tests. This presentation is (loosely) based on the joint work [1] and [2].

Keywords: McKean-Vlasov SDE, Mean-field equations, Weak error, Highorder scheme, Superlinear growth

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Deep learning for continuous-time stochastic control with jumps

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Abstract

In this paper, we introduce a model-based deep-learning approach to solve finite-horizon continuous-time stochastic control problems with jumps. We iteratively train two neural networks: one to represent the optimal policy and the other to approximate the value function. Leveraging a continuous-time version of the dynamic programming principle, we derive two different training objectives based on the Hamilton–Jacobi–Bellman equation, ensuring that the networks capture the underlying stochastic dynamics. Empirical evaluations on different problems illustrate the accuracy and scalability of our approach, demonstrating its effectiveness in solving complex, high-dimensional stochastic control tasks with an emphasis on financial problems.

Basis development of the fractional Wiener chaos expansions for the analysis of stochastic models driven by fractional Brownian motion

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Abstract

Many real-life processes are modeled with stochastic differential equations (SDEs) that include fractional derivatives in addition to fractional Brownian motion (FBM). These models still require developing techniques for proper analysis and statistical quantifications. In this talk, we develop a new practical basis for the stochastic processes motivated by or including fractional Brownian motion. The background theory is outlined with the conditions for existence and uniqueness. The new basis constructs a complete set based on the fractional Sine/Cosine or Hermite polynomials with orthogonal property that can be used in analyzing and computing the process statistics. The developed basis is used to analyze some well-known models both analytically and/or numerically commonly appear in financial modeling and other applications. The developed basis enables for practical application of the fractional Wiener chaos expansion (FWCE) and the results show its efficiency compared with other analysis techniques.

Keywords: Stochastic differential equations, Fractional Brownian motion, Fractional Wiener chaos expansion, Financial models

Modelling the role of hedgers and speculators

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Abstract

As the EU ETS has matured, financial actors have increasingly participated alongside compliance entities, raising concerns about the balance between hedging and speculative activities. Our project addresses the critical issue of distinguishing between these two types of market behavior and understanding their respective impacts on market dynamics, especially on monthly futures.

Our central research question is how do hedgers and speculators behave in the EU ETS futures market, and what are the implications of their actions for market liquidity. To explore this question, we use the weekly Commitment of Traders (CoT) reports and derive a set of metrics from the position changes of each trader category. We use these metrics to evaluate the extent and nature of their trading behavior.

Methodologically, we apply econometric models to estimate the relationship between position changes and market returns. These models are used to evaluate whether different types of participants (i.e., banks, funds, and commercials) engage in momentum trading, provide liquidity, or respond predictably to market signals.

The following results have been obtained thus far: The T-index from Working (1960) confirms a growing share of financial actors. The development of open interest shows that speculative activity is predominantly concentrated in front-year December futures contracts, while hedging is more common in March and other December contracts. Changes in fund positions significantly affect short-term returns, suggesting a role in liquidity provision.

Depending on future results, possible policy implications could include the need for regulators to consider targeted oversight mechanisms to prevent speculative activity from undermining the environmental and economic objectives of the EU ETS. Allowing for a more specific distinction between hedging and speculative positions requires additional data and enhanced transparency in market reporting.

On model improvement algorithms: an application to interest rates determination

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Abstract

In this work we address the problem of the determination of an adequate interest rate, at the emission date, by considering models that establish a relation between the interest rate and a collection of social, economic and financial factors of the country. We show that starting with a reasonable model we may, by means of neural networks and generalised linear fittings, to improve the model. We present a two step algorithm that allows, at each step, to sequentially improve the successive models by reducing the error committed using the model.

Keywords: Nominal Interest Rate, Stochastic Algorithm, Generalised Linear Models, Neural Networks.

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Measuring the impact of socially responsible investments on portfolio performance using the Shapley value

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Abstract

This paper assesses the impact of Environmental, Social and Governance (ESG) ratings on portfolio performance using the Shapley value. The analysis focuses on two characteristic functions, the Sharpe Ratio and the Value at Risk, and is applied to both the Minimum Variance Portfolio and the Maximum Sharpe Ratio Portfolio. Results are examined separately for periods of higher and lower market volatility to identify potential differences in ESG contributions. The paper finds that responsible investment rating impact on portfolio performance changes with market conditions. High and Medium rating portfolios tend to deliver better risk-adjusted returns during volatile periods, whereas Low rating portfolios perform more strongly in stable markets. This suggests a possible trade-off between sustainability and financial performance which varies depending on the market environment.

Keywords: Risk, Shapley value, ESG, Portfolio, Sharpe ratio, VaR

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Neural network empowered liquidity pricing in a two-price economy under conic finance settings

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Abstract

In the article at hand neural networks are used to model liquidity in financial markets, under conic finance settings, in two different contexts. That is, on the one hand this paper illustrates how the use of neural networks within a two-price economy allows to obtain accurate pricing and Greeks of financial derivatives, enhancing computational performances compared to classical approaches such as (conic) Monte Carlo. The methodology proposed for this purpose is agnostic of the underlying valuation model, and it easily adapts to all models suitable for pricing in conic financial markets. On the other hand, this article also investigates the possibility of valuing contingent claims under conic assumptions, using local stochastic volatility models, where the local volatility is approximated by means of a (combination of) neural network(s). Moreover, we also show how it is possible to generate hybrid families of distortion functions to better fit the implied liquidity of the market, as well as we introduce a conic version of the SABR model, based on theWang transform, that still allows for analytical bid and ask pricing formulae.

Keywords: Conic finance, Liquidity, Neural network, Concave distortions

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Navigating supply shocks: sector resilience and production prices through stochastic input-output modeling

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Abstract

This study develops a novel multivariate stochastic framework for assessing systemic risks-such as climate and nature-related shocks-within production or financial networks. By embedding a linear stochastic fluid network-interpretable as a generalized vector Ornstein-Uhlenbeck process-into the economic topology of interdependent industries, see [1], the model captures how physical shocks (e.g., extreme climate events or geopolitical disruptions) propagate through input-output (IO) linkages and affect sectoral price dynamics. The framework extends traditional IO models with advanced stochastic and dynamic features, enabling a quantification of both direct and indirect transmission channels of supply-cost shocks to production prices. Contributing to the literature on stochastic IO and Markovian networks, see [3], the model introduces the concept of divisible shocks, allowing for finer-grained simulation of adaptation responses and resilience across sectors. Empirical calibration leverages realworld economic data, including IO tables and historical industrial price indices. Sensitivity analyses are conducted using distributional risk measures, as CoVaR, see [2], offering new tools for climate stress testing and medium-to long-term risk assessment. Our findings support the optimal design of supply risk management strategies, including policy interventions and decentralized adaptation incentives for systemic stability under environmental stress..

Keywords: Multivariate stochastic processes, Production prices, Divisible shocks, Input-output tables, Linear stochastic fluid network

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Bayesian quickest double disorder detection problems with linear delay penalty

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Abstract

The quickest double disorder detection problem seeks to determine two subsequent times of alarms which are as close as possible to the unknown times of disorders at which the observation process changes its probability characteristics. We study the Bayesian problem of detecting changes in the drift rate of an observable Brownian motion with linear penalty costs for a detection delay. The optimal subsequent times of alarms are found as the first times at which the posterior probabilities of the occurrence of the disorders exit certain connected sets. The method of proof is based on the reduction of the initial problem into an appropriate two-dimensional double optimal stopping problem and the analysis of the associated parabolic-type free-boundary problems. We provide closed form expressions for the value function and the nonlinear Fredholm-type integral equations for optimal stopping boundaries for the posterior probability processes.

This project is discussed with Prof. A. N. Shiryaev and continues the topics of [1]-[2].

Keywords: Quickest disorder detection problem, Two-dimensional diffusion process, Two-dimensional double optimal stopping problem, Stochastic boundary, Parabolic-type free-boundary problem, Nonlinear Fredholm integral equation, Change-of-variable formula with local time on surfaces.

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Daily leverage and long-term investing using leveraged exchange traded funds

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Abstract

This paper explores the potential of leveraged Exchange Traded Funds (LETFs) for long-term investors and lifecycle portfolios. Leverage can increase welfare by enabling strategies that match the risk appetite of risk-tolerant investors, or by increasing financial wealth exposure to compensate for the illiquidity of human capital. We find LETFs to be suitable for both purposes with a caveat: risks associated to LETFs make it worthwhile typically only if the investor is sufficiently risk-tolerant. We also solve a dynamic portfolio optimization problem taking leverage costs and limits into account. We find that the optimal leverage target is fairly insensitive to typical leverage costs, and that welfare gains of relaxing leverage constraints are sizeable for risk tolerant investors. In our suitability analysis we study the risks of modelling discretely leveraged returns with geometric Brownian motion, as well as the probability of LETFs crashing over horizons of up to 40 years derived from extreme value theory and historical data.

Keywords: Leveraged exchange traded funds, Portfolio optimization, Risk analysis

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Option pricing: quality versus quantity in the era of Big Data

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Abstract

This study investigates the relative importance of data quality versus quantity in machine learning-based option pricing within a controlled Black-Scholes framework. Using simulated datasets, we analyze how distortions of volatility or option prices affect model performance across varying datasets.

Our findings reveal the robustness of machine learning models, such as random forests, to the volatility input, but their extreme sensitivity when it comes to the quality of the output price data.

These results emphasize that in financial machine learning applications, focusing on quality of data rather quantity can be more beneficial, carrying significant implications for practical trading and risk management strategies.

Keywords: Option pricing, Data distortion, Random forests, Robustness

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Robust equilibrium asset and option pricing

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Abstract

In this paper, we study asset and option pricing implications of Knightian uncertainty about capital shocks in a general equilibrium production-based jump-diffusion model with recursive preferences. Our model reproduces several directional properties of prices in financial markets such as negative variance premium, negative skewness premium and implied volatility skew. Our calibrated model to economic and financial data shows that options demand increases in the presence of ambiguity, which implies an upward shift in the implied volatility curve. Moreover, the calibrated model requires a low risk aversion coefficient of 2.64 to match the high equity premium and low risk free rate verified in the data. Finally, we compute the maximum consumption tax that society would be willing to pay to change the economy so that model uncertainty is eliminated. The results indicate significant welfare costs of model uncertainty.

Keywords: Knightian uncertainty, Catastrophes, Implied volatility, Welfare costs

Regression-based estimation of state-dependent volatility in project simulation models

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Abstract

Project volatility plays a critical role in risk analysis and in the application of real options methods. Accurate volatility estimation in simulation-based models requires accounting for changes over time as well as variations with the project's state at each time point. Existing approaches for estimating state-dependent volatility rely on two-level simulations, producing separate estimates for each combination of time and project state. While a regression-based method has also been proposed, its use has been limited to estimating unconditional volatility at the project's initial period, as far as the author is aware. This study extends this regression-based approach, allowing the estimation of volatility as a function of both time and project state. The proposed approach is compared with existing state-dependent volatility estimation techniques, focusing on both computational efficiency and accuracy.

Keywords: Project volatility, Volatility estimation, Simulation models, Real options

A methodological revisit of green bond premium

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Abstract

Do firms have access to a lower cost of capital when funding their green projects by choosing green bonds instead of vanilla ones? This question has prompted several papers to answer it from the seminal paper of Flammer [1]. However, the results are mixed and conflicting. Different studies employ varied samples and approaches. Consequently, there is no clear and definitive answer to this topic. Are the differences a result of the varying methodologies? Our study examines all corporate green bonds issued from 2013 to 2024. We utilise both a matching approach and a regression approach to identify whether yields and yield spreads differ between green and vanilla bonds. We observed that the results regarding yields and spreads are distinct, which is not clearly stated in the literature.

Keywords: Green bonds, Cost of capital, Yield spreads, Corporate finance, Empirical methods

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Fourier-Laplace transform discontinuities and computation in the Volterra Stein-Stein model: a Fredholm–Wishart approach

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Abstract

We investigate analytical and numerical challenges arising in the computation of the Fourier-Laplace transform for the Volterra Stein-Stein model, where the volatility is driven by a Volterra-type Gaussian process. A key difficulty stems from the complex square root of a Fredholm determinant, which becomes discontinuous when the determinant crosses the negative real axis. We characterize these crossings and provide a corrected expression for the joint Fourier-Laplace transform of the log-price and integrated variance. Furthermore, we propose a new derivation of the transform by interpreting the joint law of the integrated variance and log-price as the infinite-dimensional limit of a Wishart distribution. This novel approach naturally yields a convergent numerical method, for which we establish a convergence rate. Applying our algorithms to Fourier-based pricing in the rough Stein-Stein model, we achieve a significant increase in accuracy while drastically reducing computational cost compared to existing methods. This presentation is based on the work [1] and an ongoing working paper.

Keywords: Volterra Stein-Stein model, Fredholm determinant, Fourier-Laplace transform, Complex discontinuities, Fourier pricing, Wishart distribution

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Risk-adjusted estimation and graduation of transition intensities for disability and long-term care insurance: a multi-state model approach

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Abstract

This paper introduces a framework for estimating transition intensities in a multi-state model for Disability and Long-Term Care Insurances. We propose a novel methodology that integrates observable risk factors, such as demographic and lifestyle variables, into the estimation and graduation of transition intensities. The model features four states: autonomous, dead, and two intermediate states representing varying disability levels, providing a detailed view of disability/lack of autonomy progression. Transition intensities are graduated using a parametric approach based on the Gompertz-Makeham law and Generalized Linear Models. To illustrate the proposed framework, we simulate a dataset with individual risk profiles and model trajectories, mirroring Portugal's demographic composition. This allows us to derive a functional form (as a function of age) for the transition intensities, stratified by relevant risk factors, thus enabling precise risk differentiation. The results offer a robust basis for developing tailored pricing structures in the Portuguese market, with broader applications in actuarial science and insurance. By combining granular disability modelling with risk-factor integration, our approach enhances accuracy in premium setting and risk assessment.

Keywords: Multi-state models, Long-term care, Disability insurance, Transition intensities approach, Graduation, Data simulation

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Port-Hamiltonian systems in quantitative finance

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Abstract

TBA

New perspectives on analytic solvability of stochastic volatility models

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Abstract

Moment generating functions (mgfs) of the terminal log-asset price and integrated variance of stochastic volatility models conditional on the terminal variance value are required in exact simulation algorithms and Fourier based algorithms for pricing European path dependent options. [1] initiate the analytic derivation of conditional mgf of integrated variance of the Heston model based on related analytic results for the Bessel bridge. [2] and [3] employ different techniques of measure changes to obtain the conditional mgfs of the Heston model, multidimensional Wishart stochastic volatility model, 4/2-model and Ornstein-Uhlenbeck model. In this paper, we develop systematic and comprehensive measure change techniques that provide effective derivation procedures for the associated conditional mgfs. We establish an interesting linkage between joint conditional mgfs and their unconditional counterparts. We reveal the relations between our framework and other analytic derivation procedures. Interestingly, the conditional mgfs under the 4/2-model can be deduced from those under the Heston model via an appropriate measure change.

Keywords: Stochastic volatility models, Moment generating functions, Analytic solvability, Measure change techniques, Feynman-Kac representation formula

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A rank-based reward between a principal and a field of agents: application to energy savings

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Abstract

In this talk, we consider the problem of a Principal aiming at designing a reward function for a population of heterogeneous agents. We construct an incentive based on the ranking of the agents, so that a competition among the latter is initiated. We place ourselves in the limit setting of mean-field type interactions and prove the existence and uniqueness of the equilibrium distribution for a given reward, for which we can find an explicit representation. Focusing first on the homogeneous setting, we characterize the optimal reward function using a convex reformulation of the problem and provide an interpretation of its behaviour. We then show that this characterization still holds for a specific type of heterogeneous populations. For the general case, we propose a convergent numerical method which fully exploits the characterization of the mean-field equilibrium. We develop a case study related to the French market of Energy Saving Certificates based on the use of realistic data, which shows that the ranking system allows to achieve the sobriety target imposed by the regulation.

An efficient shared socioeconomic pathways based methodology for assessing climate risks of a large credit portfolio

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Abstract

We examine climate-related exposure within a large credit portfolio, addressing both transition and physical risks. We develop a modeling methodology that starts from the Shared Socioeconomic Pathways (SSP) scenarios and ends with the assessment of portfolio losses. The SSP scenarios affect each obligor's physical risk through a DICE-inspired damage function, and their transition risk through production decisions that require optimal adaptation. To achieve optimal production, each obligor allocates various energy sources to align its GHG emission trajectories with SSP objectives, accounting for uncertainties in consumption. This results in a high-dimensional Gaussian factor model, which we reduce using Polynomial Chaos Expansion and Principal Component Analysis, leading to an efficient and accurate simulation of credit losses.

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Semi-static hedging of volumetric risk in energy markets

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Abstract

Power purchase agreements (PPAs) play a pivotal role in the green energy transition by locking in energy prices for uncertain future production from renewable plants—often up to 10 or 15 years. The value of a PPA is largely determined by the joint distribution of future production rates and forward energy prices. In this talk, we present quantitative methods for pricing and hedging PPAs. For this, we develop a coupled model for forward electricity prices and renewable power production indices using an HJM formulation. The use of a Wishart-type stochastic covariance model allows us to capture the complex covariance structure between future production rates and forward energy prices. We derive semi-closed form solutions for the (semi-static) variance-optimal price and hedge and analyse the effec- tiveness of this integrated approach on mitigating the volume and price risks intrinsic to PPAs com- pared to a Delta-hedging strategy and a fully static one consisting of a portfolio of power and weather derivatives.

Keywords: Volumetric risk, PPAs, Stochastic covariance

Deep joint learning valuation of Bermudan swaptions

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Abstract

This work (see [1] for further details) addresses the problem of pricing involved financial derivatives by means of advanced deep learning techniques. More precisely, we methodically integrate several sophisticated neural network-based concepts like differential machine learning [2], Monte Carlo simulation-like training samples and joint learning to come up with an efficient numerical solution. The application of the latter development represents a novelty in the context of computational finance. We also propose a novel design of interdependent neural networks to price early-exercise products, in this case, Bermudan swaptions. The improvements in efficiency and accuracy provided by the approach proposed here is widely illustrated throughout a range of numerical experiments. Moreover, this novel methodology can be extended to the pricing of other financial derivatives.

Keywords: Bermudan swaptions, Neural networks, Differential machine learning, Joint learning, Monte Carlo sampling

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Neural term structure of additive process for option pricing

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Abstract

Accurately modeling asset price dynamics is central to option pricing. While Lévy processes have long been used for this purpose, they are often too rigid to capture real-world market behavior. Additive processes offer a more flexible alternative by allowing time-dependent dynamics, but this added flexibility introduces a challenge: calibrating a complicated set of time-varying parameters. Traditional approaches address this by hand-designing parametric forms for each function -a process that is empirical, arbitrary, and prone to model misspecification. In this talk, I will present a new method that utilizes neural networks to model the term structure of these time-dependent parameters directly. By learning the shape of these functions from data rather than imposing them, our approach reduces the risk of misspecification while maintaining tractability for option pricing. We show how this neural term structure model can be integrated into the additive process framework and evaluate its performance using real market data from S&P 500 options. The results demonstrate improved accuracy and adaptability compared to traditional parametric approaches.

Supervised classification for interacting particles

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Abstract

In this talk, we present a supervised classification method for K distinct interacting particle systems, each characterized by a different drift coefficient function, within the framework of the McKean-Vlasov equation. In these systems, particles are identically distributed but not independent. The central question we address is: given discrete observations of a new particle, how can we determine to which system it belongs? Our approach relies on a plug-in classification rule and requires the estimation of the drift functions.

The role of expert judgement in insurance internal model for operational risk

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Abstract

Estimating correlations in operational risk is a core requirement for internal models under the Solvency II framework, but the sparse nature of operational losses makes it difficult to apply standard methods effectively [1]. In this paper, we introduce a semiparametric Gaussian copula-based model (see also [2, 3]) that combines flexibility and simplicity: on the one hand, non-null losses can be described by a generic marginal distribution, on the other, we derive the likelihood and present a fast simulation algorithm. We propose two semi-parametric estimators for correlation both consistent and asymptotic normal, deriving some relevant properties. Moreover, we obtain confidence intervals with both an analytic asymptotic technique [4] and a semi-parametric bootstrap.

We consider the database of operational losses in ORX, the largest operational risk management association in the financial services sector that includes all major insurance companies at world level [5]. Even considering all losses observed in the main insurance companies in all western countries over a long time-interval, we observe that it is not possible to estimate the correlation even for a very simplified correlation structure, similar to that used in the standard Solvency II framework. A clear policy implication follows from this study: it highlights the key role of expert judgment in internal models for operational risk, as statistical methods alone cannot provide the minimal precision necessary in any insurance company.

Keywords: Operational risk, Semiparametric copula, Correlation estimation, Expert Judgement, ORX

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Estimating default intensity using Credit Default Swap (CDS) data

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Abstract

Credit Default Swaps (CDS) are financial instruments that enable market participants to hedge against or speculate on credit risk. As such, CDS prices provide valuable insights into investors' market sentiment. This paper aims to estimate and analyze the term structure of risk-neutral default intensities using CDS market data. The estimation is carried out using the O'Kane-Turnbull model [1], applied to CDS spreads across a range of countries and firms operating under varying economic conditions during the study period.

To further capture the dynamics of short-term default intensities, the Vasicek model [2] is employed, modeling them as a mean-reverting process. The resulting term structure of default probabilities is then compared with that derived from the O'Kane-Turnbull model, allowing for an evaluation of the relevance of the mean-reversion assumption in default risk estimation. The empirical analysis includes both simulated and real market data to assess model performance and robustness.

Keywords: Reduced-form credit risk models, Credit Default Swaps, Default intensities.

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Online convex reinforcement learning and applications to energy management problems

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Abstract

This presentation investigates online reinforcement learning algorithms for controlling large multi-agent systems in non-stationary environments with unknown dynamics. Our framework is motivated by a demand-side management problem of controlling a large number of thermal electrical appliances in real time so that their average consumption matches a target consumption profile to help balance energy supply and demand. Although motivated by the electricity sector, the proposed algorithms are general and applicable to many fields, such as logistics, economics and ecology.

The Volterra Stein-Stein model with stochastic interest rates

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Abstract

We introduce the Volterra Stein-Stein model with stochastic interest rates, where both volatility and interest rates are driven by correlated Gaussian Volterra processes. This framework unifies various well-known Markovian and non-Markovian models while preserving analytical tractability for pricing and hedging financial derivatives. We derive explicit formulas for pricing zero-coupon bond and interest rate cap or floor, along with a semi-explicit expression for the characteristic function of the log-forward index using Fredholm resolvents and determinants. This allows for fast and efficient derivative pricing and calibration via Fourier methods. We calibrate our model to market data and observe that our framework is flexible enough to capture key empirical features, such as the humped-shaped term structure of ATM implied volatilities for cap options and the concave ATM implied volatility skew term structure (in log-log scale) of the S&P 500 options. Finally, we establish connections between our characteristic function formula and expressions that depend on infinite-dimensional Riccati equations, thereby making the link with conventional linear-quadratic models.

Keywords: Gaussian Volterra processes, Volatility, interest rate, Memory, Fredholm resolvents and determinants, Fourier pricing, Riccati equations

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Oil as a spoilsport in ESG investing? An analysis of the correlation effects of stocks in the ESG spectrum

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Abstract

In this talk we compare the interactions between the returns of ESG-strong stock investments and crude oil with those of ESG-weak stock investments and crude oil. Using a dynamic conditional correlation analysis and a wavelet coherence analysis, it is found that these interactions differ significantly from each other.ESG-strong stock investments correlate significantly higher with the returns of crude oil than ESG-weak stock investments.

A number of practical implications can be derived from the results of the analysis. For example, ESG-strong stocks are better suited as a hedge against rising oil prices than ESG-weak stocks.

Rising oil prices should not be seen as a 'spoilsport' for the socially intended channelling of capital flows into sustainable channels, which, at least from the perspective adopted here, makes state subsidies for energy redundant.

Stochastic graphon games with memory

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Abstract

We study finite-player dynamic stochastic games with heterogeneous interactions and non-Markovian linear-quadratic objective functionals. We derive the Nash equilibrium explicitly by converting the first-order conditions into a coupled system of stochastic Fredholm equations, which we solve in terms of operator resolvents. When the agents' interactions are modeled by a weighted graph, we formulate the corresponding non-Markovian continuum-agent game, where interactions are modeled by a graphon. We also derive the Nash equilibrium of the graphon game explicitly by first reducing the first-order conditions to an infinite-dimensional cou- pled system of stochastic Fredholm equations, then decoupling it using the spectral decomposition of the graphon operator, and finally solving it in terms of operator resolvents. Moreover, we show that the Nash equilibria of finite-player games on graphs converge to those of the graphon game as the number of agents increases. This holds both when a given graph sequence converges to the graphon in the cut norm and when the graph sequence is sampled from the graphon. We also bound the convergence rate, which depends on the cut norm in the former case and on the sampling method in the latter. Finally, we apply our results to various stochastic games with heterogeneous interactions, including systemic risk models with delays and stochastic network games.

Beyond the Leland strategies

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Abstract

We present a novel approach to the super-replication problem in a discrete financial model with proportional transaction costs. Unlike the classical Leland strategy, which relies on asymptotic approximations by increasing the number of revisions and decreasing transaction costs, our method provides an exact solution for a fixed number of revisions and constant transaction costs. The approach requires neither the existence of a risk-neutral probability measure nor any price model assumptions, making it readily applicable to real data. It is based on an Absence of Immediate Profit (AIP) condition and uses distorted Legendre-Fenchel conjugations to characterize super-replication prices. This provides an explicit backward-forward scheme resolution for the superhedging problem [1].

Keywords: Super-replication, Transaction costs, Leland strategy, Legendre-Fenchel conjugation, Absence of immediate profit

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Optimal portfolio choice with comfortable consumption

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Abstract

The text of the abstract In this paper we investigate a Merton-type portfolio optimization problem with a minimum comfortable consumption constraint, utilizing a stochastic control approach. By translating the Hamilton-Jacobi-Bellman (HJB) equations into second-order ordinary differential equations (ODEs) through a novel method, we precisely characterize the set of candidate value functions. We then identify the optimal consumption rate, investment strategy and the value function explicitly by extending the recent stochastic perturbation method presented in Herdegen, Hobson and Jerome (2021) [1]. This approach can be applied to derive explicit solutions for other portfolio choice problems under constraints, with detailed studies of the corresponding HJB equations. In addition, we have extended the model when inflation is considered. We also discuss some applications, such as retirement funds, pension funds, endowment portfolios and the AK model for economic growth.

Keywords: Portfolio optimization, Minimum consumption, CRRA utility, Fenchel-Legendre transformation, Stochastic perturbation

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The discrete-time 4-factor PDV model: calibration under $\mathbb{P}$ and $\mathbb{Q}$

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Abstract

This talk presents calibration approaches under both the risk-neutral measure $\mathbb{Q}$ and the historical measure $\mathbb{P}$ for a discrete-time version of the 4-factor path-dependent volatility (PDV) model introduced by Guyon and Lekeufack. We first illustrate the model's ability to fit option data across multiple dimensions, including the VIX time series, the SPX volatility surface, and joint SPX/VIX smiles. We then turn to the estimation of the model under the historical measure via maximum likelihood and show that the considered PDV model outperforms existing models in the literature based on likelihood metrics. The talk also discusses the proximity between the $\mathbb{P}$-estimated model and the risk-neutral measure implied by option market data. The results indicate that these measures are fairly close, supporting both the model's consistency with market data and the hypothesis of a strong endogeneity in the joint formation of the $\mathbb{P}$ and $\mathbb{Q}$ measures. Building on this observation, we introduce a new estimation approach that combines $\mathbb{P}$ and $\mathbb{Q}$ information to enhance calibration robustness. Its performance is then compared with standard methods.

Keywords: Volatility modeling, Path-dependent volatility, Smile calibration, Joint S&P 500/VIX smile calibration.

Polynomial Volterra processes

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Abstract

Recent studies have extended the theory of affine processes to the stochastic Volterra equations framework. In this talk, I will describe how the theory of polynomial processes extends to the Volterra setting. In particular, I will explain the moment formula and an interesting stochastic invariance result in this context. Potential applications to fractional volatility models will be discussed.

Benford's law: distributional properties, simulations, and real-world conformity tests

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Abstract

This study examines the statistical foundations of Benford's Law, a phenomenon that describes the non-uniform distribution of leading digits in naturally occurring numerical datasets. Recognized as a valuable tool for financial statement analysis, Benford's Law supports more informed investment decision-making. The research seeks to enhance understanding of the statistical distributions that conform to Benford's pattern, with a focus on those relevant to real-world applications. Through simulation experiments, we validate theoretical predictions. Additionally, we explore the integration of Benford's Law into machine learning models, with a particular focus on combining it with Graph Neural Networks, and we highlight potential applications of this integration.

Keywords: Benford's law, Machine learning methods, First digits law, Fraud detection, Statistical tests

Application of generalized linear models in assessing the influence of acquisition costs on insurance premiums

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Abstract

This paper explores the application of Generalized Linear Models to assess the impact of acquisition costs on the insurance premium income of insurance companies operating in the Republic of Serbia. The analysis focuses exclusively on acquisition costs as the sole independent variable, encompassing commissions for concluded contracts, marketing expenditures, employee-related costs, and other operational expenses associated with acquiring new policyholders. The dependent variable follows a Bernoulli distribution, taking values of 0 or 1 depending on whether the company achieved a high premium level. The empirical analysis was conducted on a sample of insurance companies. Special attention is given to the role of marketing in shaping insurance demand, designing product offerings, and building client trust. By applying the GLM approach, the study estimates the probability of achieving higher premium income based on the level of investment in acquisition costs. The results indicate a statistically significant correlation between acquisition costs and the likelihood of generating higher premium revenue. This research provides valuable insights into the financial efficiency of insurance operations and emphasizes the importance of strategic investment in pre-sale activities. It concludes that a well-structured acquisition cost strategy, supported by actuarial risk assessment, can enhance competitiveness and ensure sustainable growth in the insurance sector.

Keywords: Acquisition costs, Premium, Generalized linear model

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Benchmarking of index funds with transaction costs

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Abstract

This paper investigates optimal dynamic trading strategies to benchmark capital-intensive financial indices using a constrained sub-portfolio, while accounting for transaction costs arising from market impact. Based on the work of [3], we develop a rigorous framework that combines stochastic portfolio optimization with market microstructure modeling, to address the dual task of outperforming the target index and managing the cost-efficiency tradeoff inherent when rebalancing. Our dynamic programming approach is also similar to that used in [1, 2] to solve a portfolio benchmarking problem. Although, the fundamental difference between these approaches and ours is that we use a sub-portfolio, thus constraining the strategy to fewer assets. Through numerical simulations incorporating realistic market impact functions, we demonstrate that our dynamic strategy achieves superior risk-adjusted returns compared to the target index fund and additionally to some type of Markowitz optimal portfolios.

Keywords: Optimal trading strategy, Transaction costs, Sub-portfolio, Index funds

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Stochastic differential equations harvesting models: simulation and numerical solution

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Abstract

Harvesting is a fundamental activity that significantly influences both human society, by supplying food, and the environment, by consuming resources. Maintaining an equilibrium is key for ecosystem integrity and the continued viability of harvesting practices. Therefore, harvesting policies should aim to achieve this balance by implementing sustainable quotas, regulated by effort.

Effort, in fisheries, refers to the operational plan, quantifiable by factors such as the number of vessels, workers, or hours at sea. This inherent structure imposes significant rigidity on organizations due to the substantial costs associated with fluctuating effort levels. Consequently, highly volatile effort policies, while useful for guiding profit comparisons, are impractical for direct application.

This work determines an optimal variable effort by numerically solving a non-linear Partial Differential Equation. The resulting optimal variable effort yields higher profits, which serve as a reference for assessing the feasibility of various strategies through comparative analysis of their outcomes.

We modelled prices using a quadratic function and a Geometric Brownian Motion, and incorporated a discount factor that varies over time. For the quadratic price function, a penalized effort strategy was also implemented to determine and assess the resulting effort behaviour and associated profit, comparing these against reference values.

A strength parameter, ε, significantly influences profit by penalizing substantial effort changes. Higher ε reduces profit and mitigates sharp oscillations, yielding a more stable, albeit constantly adjusted, effort. This approach addresses social issues (arising from low or zero efforts), while still presenting logistical challenges stemming from frequent oscillations.

Keywords: Stochastic differential equations, Partial differential equations, Halmiton-Jacobi-Bellman equation, Numerical methods

Power purchase agreements: a renewable energy approach

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Abstract

Electricity derivatives represent a tool to hedge against price fluctuations and to meet sustainability targets. Roughly, a Renewable Energy (or Green) Power Purchase Agreement (PPA) is a derivative where one party produces electricity and the other purchases it. In order to model electricity prices, we consider the wind infeed as the unique underlying stochastic factor, jointly with two time-dependent functions: solar infeed and demand [1]. Therefore, the PPA price satisfies a 2-dimensional PDE model, where the spatial variables are the wind infeed and the accumulated electricity price. Unlike the usual exponential setting, the proposed model allows possible negative prices that may appear due to the mismatching between demand and renewable energy infeed. Parameters of the model are estimated from historical data [2] and this estimation allows to compute an approximated solution for the PDE under the fast mean-reverting framework of [3].

Keywords: Power Purchase Agreement (PPA), Wind infeed, Electricity price

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Optimal consumption policy in a carbon-conscious economy: a machine learning approach

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Abstract

Due to the significant carbon emissions generated by various sectors of the economy, fast economic growth can hinder efforts to combat climate change. We study this trade-off by considering an optimal control problem based on the single-good economy model of Borissov/Bretschger [1] in discrete time. There, a social planner aims to determine an optimal consumption policy while ensuring simultaneously that the economy grows and overall emissions do not breach a given climate budget. We develop a dynamic programming framework to analyse this climate-constrained optimisation problem and show that the optimal consumption policies for the problem with finite-time horizon converge pointwise to the optimal consumption policy with an infinite-time horizon. To address the computational complexity inherent in high-dimensional policy spaces, we use a machine learning approach to find an approximate optimal solution to the social planner's control problem. The aforementioned framework is initially implemented in a single-economy setting and then extended to a multi-country model with heterogeneous characteristics.

Keywords: Optimal control, Machine learning, Carbon pollution, Climate budget, Optimal consumption policy, Intertemporal utility

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Hamiltonian Monte Carlo simulations to estimate extended stochastic volatility models within a time-deformed intraday framework

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Abstract

Stochastic volatility (SV) models are essential for capturing the dynamic nature of volatility in financial time series. Bayesian inference offers a principled framework for estimating these models, with Markov Chain Monte Carlo (MCMC) methods aiding in sampling from their posterior distributions. Among MCMC techniques, Hamiltonian Monte Carlo (HMC) is notable for its ability to efficiently explore high-dimensional parameter spaces. This paper examines the application of HMC methods to SV models within a time-deformed intraday framework, highlighting algorithmic advancements and computational strategies that enable their implementation in large and complex data sets. The adaptation of SV models, typically used with daily data, to high-frequency intraday regimes presents additional challenges for standard sampling methods due to their poor mixing and convergence properties. HMC tackles these issues by utilizing gradient information within the context of a potential energy function, a strategy based on the principles of differential geometry. Our implementation uses automatic differentiation, as provided by the JAX package, to allow scalable and flexible sampling across various SV model structures. This approach produces robust parameter estimates for well-specified models while assisting in the diagnostics and identification of ill-posed ones, thereby enhancing the robustness and credibility of subsequent financial inference.

Keywords: Hamiltonian Monte Carlo, Bayesian estimation, Stochastic volatility

Using adaptive LASSO to improve portfolio strategies

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Abstract

This paper explores the predictability of monthly U.S. stock returns using the adaptive LASSO method applied to firm-specific characteristics over the period from June 1990 to December 2022. By effectively selecting relevant predictors and handling high-dimensional data, adaptive LASSO improves return forecasts compared to traditional models. Key predictors identified include lagged returns, mean log-volumes, market capitalization, dividend yield, and R&D expenditures. Building on these forecasts, we construct two threshold-based portfolio strategies: Adaptive LASSO 1/N (equal-weighted) and Adaptive LASSO SR (Sharpe ratio-weighted), both incorporating a 0.3% transaction cost and a no-trade region to reduce turnover. The Adaptive LASSO SR portfolio outperforms standard benchmarks, delivering a 337.20% cumulative return and an annualized Sharpe ratio of 76.74%, while demonstrating resilience to the presence of trading costs. Sensitivity analyses across different entry and exit thresholds reinforce the portfolio's consistent outperformance. This study contributes to the literature by (i) assessing the predictive power of firm-level characteristics using adaptive LASSO, (ii) developing transaction cost-aware trading strategies, and (iii) demonstrating the practical value of advanced regularization techniques in return forecasting and portfolio optimization.

Keywords: Adaptive LASSO, Stock return forecasting, Portfolio optimization, Cross-section features

Impact of the carbon price on credit portfolio's loss with stochastic collateral

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Abstract

This work is an extension of [1]. The aim is to propose an end-by-end modeling framework to evaluate the risk measures of a bank's portfolio of collateralized loans when the bank, the borrowers, as well as their guarantees operate in an economy subject to the climate transition.

The economy, organized in sectors, is driven by its productivity which is a multidimensional Ornstein-Uhlenbeck process while the climate transition is declined thanks to the carbon price and carbon intensities, continuous deterministic processes. We thus derive the dynamics of macroeconomic variables for each climate transition scenario.

By considering that a firm defaults if it is over-indebted i.e. its market value - depreciated due to the carbon price - becomes less than the market value of its debt, we define each loan's loss at default as the difference between Exposure at Default (EAD) and the liquidated collateral, which will help us to define the Loss Given Default (LGD) - the expected percentage of exposure that is lost if a debtor defaults. We consider two types of collateral: financial asset such as invoices, cash, or investments or physical asset such as real estate, business equipment, or inventory.

First, if it is a financial asset, we model the later by the continuous time version of the discounted cash flows methodology, where the cash flows growth is driven by the instantaneous output growth, the instantaneous growth of a carbon price function, and an arithmetic Brownian motion.

Secondly, for physical asset, we focus on the example of a property in housing market. Therefore, we define, as (Sopgoui, 2024) [2], its value as the difference between the price of an equivalent efficient building following an exponential Ornstein-Uhlenbeck (OU) as well as the actualized renovation costs and the actualized sum of the future additional energy costs due to the inefficiency of the building, before an optimal renovation date which depends on the carbon price process.

Finally, we obtain expressions for risk measures of a portfolio of collateralized loans as a function of various parameters and variables, mainly those linked to the climate transition, such as the carbon price and the energy efficiency of buildings. These risk measures will be used by banks, depending on the climate transition scenarios, to define their operating expenses, the fees applied to clients, as well as their economic and regulatory capital.

Keywords: Credit risk, Climate risk, Collateral valuation, Stochastic modelling, Transition risk, Carbon price, Firm valuation Loss given default

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Martingale property and moment explosions in signature volatility models

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Abstract

We study the martingale property and moment explosions of a signature volatility model, where the volatility process of the log-price is given by a linear form of the signature of a time-extended Brownian motion. Excluding trivial cases, we demonstrate that the price process is a true martingale if and only if the order of the 3linear form is odd and a correlation parameter is negative. The proof involves a fine analysis of the explosion time of a signature stochastic differential equation. This result is of key practical relevance, as it highlights that, when used for approximation purposes, the linear combination of signature elements must be taken of odd order to preserve the martingale property. Once martingality is established, we also characterize the existence of higher moments of the price process in terms of a condition on a correlation parameter.

Minimum capital requirement for non-life insurance with risk budgeting portfolios

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Abstract

We propose an optimization model to determine the minimum capital requirement that protects a non-life insurance company against unexpected losses. The model assumes that both the minimum capital and premium income are invested in financial assets and uses Conditional Value-at-Risk (CVaR) as the risk measure. This problem has already been addressed by [1] and [2]. However, unlike these studies, our model integrates the risk budgeting approach to portfolio selection with the computation of the minimum capital requirement.

The proposed approach consists of two phases. The first determines the portfolio weights that satisfy the risk budgeting principle. The second, given these weights, computes the minimum capital such that the CVaR of the insurer's loss over the solvency horizon is non-positive. In both phases, we employ a Monte Carlo scenario framework for the asset log-returns and apply cutting-plane methods to solve the resulting convex optimization problems.

Numerical results illustrate the performance of our model when financial assets contribute equally to total portfolio risk, that is, when portfolios are selected using a risk parity strategy. Regarding the insurer's liability, we consider three possible distributions, the log-normal, gamma, and Erlang mixture, and analyse how each affects the solvency capital requirement. It is worth noting that the model is not limited to these three distributions. Other distributions may also be considered.

Keywords: Solvency capital requirement, Risk budgeting, Convex optimization.

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Assessing the efficiency of insurance companies using fuzzy data envelopment analysis: evidence from Serbia

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Abstract

This article integrates fuzzy set theory into the Data Envelopment Analysis (DEA) framework to assess the operational efficiency of insurance companies in Serbia when some input and output data are imprecise. In the insurance industry, a significant portion of financial statement items, such as technical reserves, is based on actuarial estimates. Moreover, in emerging markets, financial data are often imprecise, inconsistent, or subject to managerial discretion. Operating expenses reflect internal allocation policies and accounting choices, while investment income is influenced by market volatility and may vary depending on the valuation methods used. In this study, a fuzzy DEA model is employed to address the efficiency evaluation problem under conditions of fuzzy input and output data. The proposed approach is empirically illustrated using a set of insurance companies in Serbia.

Keywords: Insurance companies, Fuzzy Data Envelopment Analysis, Efficiency.

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Sannikov's contracting problem with many agents

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Abstract

This work aims to study an extension of the celebrated Sannikov's Principal-Agent problem to the multi-Agents case. In this framework, the contracts proposed by the Principal consist in a running payment, a retirement time and a final payment at retirement. After discussing how the Principal may derive optimal contracts in the N-Agents case, we explore the corresponding mean field model, with a continuous infinity of Agents. We then prove that the Principal's problem can be reduced to a mixed control-and-stopping mean field problem, and we derive a semi-explicit solution of the first best contracting problem.

Stochastic graphon games with memory

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Abstract

Network games generalize mean field games by modeling heterogeneous interactions among agents, which are often represented by graphs. In this work, we study stochastic network games with finitely many players and non-Markovian objective functionals. We derive the Nash equilibrium explicitly by converting the first-order conditions into a coupled system of stochastic Fredholm equations and solving it via operator resolvents. Extending our analysis, we formulate the corresponding infinite-player game, where interactions are modeled using a graphon, and derive its Nash equilibrium explicitly as well. Furthermore, given a sequence of graphs that converges to a graphon, we establish that the Nash equilibria of the corresponding finite-player games converge to that of the corresponding graphon game as the number of agents increases, and we provide bounds on the convergence rate. Finally, we illustrate the applicability of our results with examples. This is joint work with Eyal Neuman.

Keywords: Mean field games, Graphon games, Stochastic control

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Overcoming misconceptions about local volatility: exact prices lead to sound continuous Markovians models.

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Abstract

Local volatility models are generally seen as insufficient for handling the many nuances of modern derivative markets. While the sub-optimality of their empirical performance in the financial practice is well-documented, this criticism often extends to alleged mathematically structural inconsistencies of such model class with the observed stylized facts, particularly in relation to the statics and dynamics of the implied volatility surface. By reverse-engineering a family of no-arbitrage call price functions, compatible with a pure jump additive process this research questions a number of such claims. We introduce a class of continuous Markov models with locally unbounded local volatility and analytical option prices, leading – by construction – to identifiable risk-neutral marginal distributions. We then specify to a significant instance where the SDE well-posedness can be shown, the Generalized Beta local volatility model (GBLV). The marginal distributions in this class are sticky-delta and in fact shared with a positive martingale discontinuous model already presented in the literature. In view of these findings, we revisit three popular, by and large accepted, claims on local volatility, namely that: A) the implied volatility smile of local volatility shifts in the opposite direction to that of the spot price moves; B) local variances stemming from jump-type asset prices lead to ill-posed local volatility models; C) positive, continuous, Markovian no-arbitrage pricing models cannot capture an inverse power law at-the-money implied volatility skew divergence around valuation time. These claims are typically regarded as valid for the whole local volatility class, but one way or another they hinge on auxiliary assumptions. Embedding the desirable properties that A, B, C negate directly in the risk neutral distributions, frees the model from the constraints that make local volatility unsuitable to capture certain phenomena, effectively sidestepping the assumptions that make it so. As a consequence, the GBLV model does not suffer from several of the drawbacks exposed by the classic critique of local volatility, and we maintain it is a fully viable model for industrial uses in option markets.

Keywords: Local volatility, Equity market skew, Pure jumps additive process, Weak solutions

Computation of Greeks under rough Volterra stochastic volatility models using the Malliavin calculus approach

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Abstract

Using Malliavin calculus techniques, we obtain formulas for computing several Greeks under different rough Volterra stochastic volatility models. In particular, we obtain formulas for rough versions of Stein-Stein, SABR and Bergomi models and show numerically the convergence.

Keywords: Computation of Greeks, Stochastic volatility models, Malliavin calculus

References

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Controllable generation of implied volatility surfaces with variational autoencoders

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Abstract

Deep generative models have demonstrated considerable potential for synthesizing implied volatility surfaces (IVS), with applications in option pricing and risk management. However, these data-driven models often lack explicit control over meaningful IVS shape attributes (e.g., volatility level, slope, etc.). To address this, we propose a controllable generative framework utilizing a Variational Autoencoder (VAE) in combination with a feature extraction algorithm for IVS. This approach can explicitly quantify IVS shape features and embeds them into the latent space of VAE, enabling disentangled representations and control over the generated surfaces, thus creating synthetic IVS data that reflect targeted market scenarios rather than generating arbitrary samples. Numerical results confirm that this generative model produces realistic IVS that adhere to user-specified characteristics, maintaining both interpretability and the flexibility of deep generative techniques.

Keywords: Generative model, Implied volatility surface (IVS), Variational autoencoder (VAE), Characteristic control, Arbitrage-free Condition

Modelling equilibrium behaviour in solar REC and offset credit markets

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Abstract

With the growing popularity of green derivative markets, including renewable energy certificates (RECs) and offset credits (OCs) markets, the problem of correctly characterizing equilibrium behaviour is important to understanding their effectiveness. In this talk, we demonstrate how to appropriately model the complex behaviour in these markets using methods from stochastic control, game theory, and machine learning. In a solar REC market, we solve for an agent's optimal strategy in a mean-field game setting, where the REC price is induced by the mean-field flow and the agents' controls through a market clearing condition. In an OC market, we employ reinforcement learning to efficiently approximate the finite-player Nash equilibrium. Through numerical experiments, we demonstrate the validity of our approaches in these markets and the financial benefits gained when a firm actively participates.

Macroscopic properties of equity markets: stylized facts and portfolio performance

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Abstract

Macroscopic properties of equity markets affect the performance of active equity strategies but many are not adequately captured by conventional models of financial mathematics and econometrics. Using the CRSP Database of the US equity market, we study empirically several macroscopic properties defined in terms of market capitalizations and returns, and highlight a list of stylized facts and open questions motivated in part by stochastic portfolio theory. In particular, we study market diversity and intrinsic volatility which are closely related to information geometry. Additionally, we study empirically the performance of the diversity-weighted portfolio in relation to macroscopic quantities.

Keywords: Stochastic portfolio theory, Market diversity, Portfolio selection

Efficient high-order smoothing methods for rainbow options on sparse grids

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Abstract

Option pricing problems give rise to partial differential equations (PDEs) with nonsmooth initial conditions. Numerical methods applied to such PDE problems, in particular high-order methods, often exhibit a deteriorated or unstable order of convergence. A way to maintain the order of convergence of high-order methods is to apply smoothing techniques to the initial conditions. These techniques often involve calculation of integrals. We identify the computational challenges of using black-box software to compute high-order smoothings in multiple dimensions. We propose an efficient numerical method to compute the smoothing of rainbow option payoffs in any number of dimensions. We compare the results with those from another efficient numerical method to compute the smoothing of various two-dimensional payoffs. Both methods can be applied to either convolution- or projection-based smoothings. We also propose an efficient way to incorporate nonuniform grids to convolution-based smoothings. We present the results in the setting of the sparse grid combination method, which mitigates the curse of dimensionality that arises when a standard tensor-product based discretization is used in multiple spatial dimensions.

Keywords: Rainbow option, Sparse grids, High-order methods

Continuous-time mean field games: a primal-dual characterization

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Abstract

This paper establishes a primal-dual formulation for continuous-time mean field games (MFGs) and provides a complete analytical characterization of the set of all Nash equilibria (NEs). We first show that for any given mean field flow, the representative player's control problem with measurable coefficients is equivalent to a linear program over the space of occupation measures. We then establish the dual formulation of this linear program as a maximization problem over smooth subsolutions of the associated Hamilton-Jacobi-Bellman (HJB) equation, which plays a fundamental role in characterizing NEs of MFGs. Finally, a complete characterization of *all NEs for MFGs* is established by the strong duality between the linear program and its dual problem. This strong duality is obtained by studying the solvability of the dual problem, and in particular through analyzing the regularity of the associated HJB equation. Compared with existing approaches for MFGs, the primal-dual formulation and its NE characterization do not require the convexity of the associated Hamiltonian or the uniqueness of its optimizer, and remain applicable when the HJB equation lacks classical or even continuous solutions.

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