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16th Actuarial and Financial Mathematics Conference

Interplay between Finance and Insurance

AG Campus, Brussels, 3-4 February 2025

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Practical info

Conference locations

Registration desk: Lounge Area
Presentations: Auditorium A
Poster session: Lounge Area
Coffee & lunch: Lounge Area
Conference dinner: University foundation, Egmontstraat 11, 1000 Brussel

Map available at http://www.afmathconf.ugent.be/index.php?page=practicalinfo

Wireless internet

Connect to network 'guest' to be automatically redirected to the Guest Portal.

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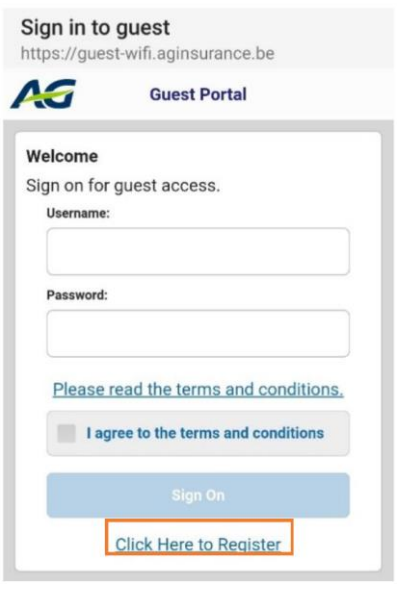

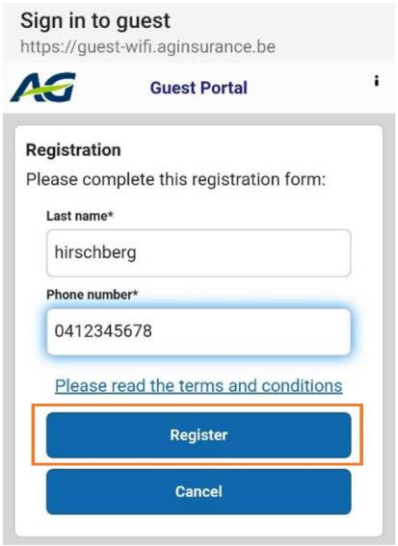

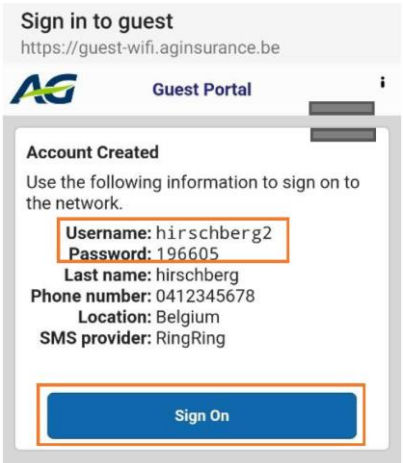

Programme Monday 3 February

09:00 – 09:20	Registration and welcome coffee
09:20 – 09:30	Welcome
	Chair: Carole Bernard
09:30 – 10:15	INVITED SPEAKER – Emmanuel Gobet, Institut Polytechnique de Paris, France **Modelling uncertainty and investment decision for adapting to climate change**
10:15 – 10:45	CONTRIBUTED TALK – Bertrand Tavin, EMLYON Business School, France **Robust portfolio allocation under dependence uncertainty**
10:45 – 11:15	Coffee break
	Chair: Frédéric Vrins
11:15 – 12:00	INVITED SPEAKER – Raffaella Calabrese, University of Edinburgh, UK **A climate scenario analysis for the European SME lending market based on the NGFS projections**
12:00 – 12:30	CONTRIBUTED TALK – Daria Sakhanda, ETH Zürich, Switzerland **Optimal Consumption Policy in a Carbon-Conscious Economy: A Machine Learning Approach**
	Chair: Ann De Schepper
12:30 – 13:00	Poster storm session
13:00 – 14:00	Sandwich lunch combined with poster session
	Chair: Karel in 't Hout
14:00 – 14:45	INVITED SPEAKER – Fred Espen Benth, University of Oslo, Norway **Hedging weather risk in energy markets**
14:45 – 15:15	CONTRIBUTED TALK – Luke Thomas Servat, Maastricht University, Netherlands **Optimal Investment with Intergenerational Solidarity**
15:15 – 15:45	Coffee break
	Chair: Hansjoerg Albrecher
15:45 – 16:15	CONTRIBUTED TALK – John Armstrong, King's College London, UK **Inter-generational cross-subsidies in UK collective defined contribution funds**
16:15 – 17:00	INVITED SPEAKER – Elena Vigna, Università di Torino and Collegio Carlo Alberto, Italy **Optimal additional voluntary contribution in DC pension schemes to manage inadequacy risk**
18:30 – 21:30	Conference Dinner at University Foundation

Programme Tuesday 4 February

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09:45 – 10:15	CONTRIBUTED TALK – Sascha Günther, Université de Lausanne, Switzerland **Modern pension design by refundable income tontines**
10:15 – 10:45	Coffee break
	Chair: Steven Vanduffel
10:45 – 11:30	INVITED SPEAKER – Fei Huang, UNSW Sydney, Australia **Fair Decision-Making via Counterfactual Sensitivity Analysis**
11:30 – 12:00	CONTRIBUTED TALK – Marie-Pier Cote, Université Laval, Canada **Causal insights on the spectrum of "fair" insurance tariffs**
	Chair: Ann De Schepper
12:00 – 12:30	Poster storm session
12:30 – 13:30	Sandwich lunch combined with poster session
	Chair: Tahir Choulli
13:30 – 14:15	INVITED SPEAKER – Emmanuel Lepinette, Université Paris Dauphine, France **Alternative technique of pricing without martingale measure**
14:15 – 14:45	CONTRIBUTED TALK – Aleksandar Arandjelović, WU - Vienna University of Economics and Business, Austria **Importance sampling for option pricing with feedforward neural networks**
14:45 – 15:15	Coffee break
	Chair: Wim Schoutens
15:15 – 16:00	INVITED SPEAKER – Julien Guyon, École nationale des ponts et chaussées, Institut Polytechnique de Paris, France **Volatility: rough or not?**
16:00 – 16:30	CONTRIBUTED TALK – Philipp Carsten Hornung, University of Copenhagen, Denmark **Optimal Smooth Consumption and its Trade-Offs**
16:30 – 16:45	Closing

Poster sessions

Monday 3 February

Nixon Shingai Chekenya, Texas Tech University, United States
Weather Shocks and Crop Abandonment: Theory and Evidence from Zambia

Zixin Feng, Macquarie University, Australia
Risk measurements for blockchain mining pools and crypto asset management

Javier Garcia Gonzalez, Tilburg University, Netherlands
Daily leverage and long-term investing using leveraged exchange traded funds

Pankaj Kumar, Jheronimus Academy of Data Science, Netherlands
Multi-Agent Deep Reinforcement Learning for High-Frequency Multi-Market Making

Yixuan Ma, Maastricht university, Netherlands
Solving Dynamic Portfolio and Consumption Problems by Going Forward in Time

Mustapha Regragui, Ghent University, Belgium
Numerical valuation of swing options: discrete exercise rights

Iván de Jesús Rodríguez Durán, Centro de Investigación en Matemáticas, Mexico
HJB equation for maximization of wealth under insider trading

Rodolphe Vanderveken, UCLouvain, Belgium
Shrinking the Covariance Matrix: A Portfolio Perspective

Tuesday 4 February

Nixon Shingai Chekenya, Texas Tech University, United States
Longevity swaps for longevity risk management in life insurance products

Dounia Essaket, Université Paris Cité, France
On the Carbon Tax in Golosov et al.'s 2014 Dynamic Stochastic General Equilibrium Central Planning Model

Agathe Fernandes Machado, Université du Québec à Montréal, Canada
Probabilistic Scoring for Unbalanced Multi-Class Classifiers: Enhancing Calibration with Nested Dichotomies

Natascha Jankowski, University of Konstanz, Germany
Life cycle consumption and portfolio choice under real interest rate risk

Yushan Liu, Ecole Polytechnique, France
Metamodeling Climate Trajectories Using Neural Networks

Massimiliano Moda, University of Antwerp, Belgium
A numerical solution for European option pricing under 2-dimensional jump-diffusion processes

Austin Riis-Due, University of Waterloo, Canada
Reinforcement Learning for Actuarial Credibility, with Extensions

Modelling uncertainty and investment decision for adapting to climate change

Emmanuel Gobet, Institut Polytechnique de Paris, France

Tackling climate change is one of the biggest challenges of today. From quantitative point of view, this is a complex program because of the numerous heterogeneous economic actors involved, all facing various uncertainties: uncertainty related to economy as it is usually considered, but also uncertainty in the transition scenario to a greener world, uncertainties related to the short-term and long-term consequences of climate change. In this presentation, I will give a couple of use-cases and quantitative models in which these issues are addressed: a) large credit portfolio encompassing both transition and physical risks, b) companies' business model evolution according to intensity reduction strategy and carbon tax costs.

Robust portfolio allocation under dependence uncertainty

Bertrand Tavin, EMLYON Business School, France
Joint work with: Eric André

In this paper, we present a solution to the problem of robust portfolio allocation for an investor facing uncertainty with respect to the dependence between risky assets' returns. We use the Multiplier Preferences framework to build a decision criterion which is robust to this uncertainty and we use copulas to model general dependence structures without additional assumptions. We study the properties of this robust portfolio allocation problem and prove the existence and unicity of its solution. Then, using Bernstein copulas, we devise a solvable approximate version. We prove the existence and unicity of the solution to the approximate problem. We then prove the convergence of the approximate solution to the exact solution when the discretization gets finer. In a numerical study, we provide comparative statics of the relationship between the level of ambiguity aversion and the robust allocations. We find that our robust portfolios are less diversified compared to the standard max-expected utility or maximum Sharpe ratio portfolios. The magnitude of this effect is driven by the level of ambiguity aversion of the considered agent. Finally, in a simulation study, we evidence the robustness of the obtained portfolios against the discovery of the true dependence model.

A climate scenario analysis for the European SME lending market based on the NGFS projections

Raffaella Calabrese, University of Edinburgh, UK
Joint work with: Luca Zanin (Prometeia)

Assessing forward-looking climate risk materiality for Small and Medium Enterprises (SMEs) loan portfolios can be challenging due to firms' poor informative disclosure on environmental matters and uncertainty in climate policies. To fill this gap, we suggest to use climate mitigation scenarios. We analyse a comprehensive dataset on 3.9 million loans to SMEs from 2013 to 2022 for three European countries (Belgium, Italy, and Portugal). We consider a survival approach with macroeconomic variables to estimate the SME probability of default. We then project the macroeconomic variables under the mitigation scenarios provided by the Network for Greening the Financial System (NGFS) with a time horizon up to 2050. Climate risks increase the projected SME default probabilities in the short term, especially under a delayed transition and a Fragmented World scenario. In the long run, the transition under a Net Zero 2050 scenario brings co-benefits regarding a lower default probability than under a delayed transition scenario or a Fragmented World scenario. Projections also suggest that insufficient climate policies to mitigate global warming can negatively impact loan portfolios through the damages from physical risk.

Optimal Consumption Policy in a Carbon-Conscious Economy: A Machine Learning Approach

Daria Sakhanda, ETH Zürich, Switzerland
Joint work with: Prof. Dr. Josef Teichmann

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 (2022) in discrete time. There, a social planner looks for the optimal consumption policy while ensuring simultaneously that the economy grows and overall emissions do not breach a given climate budget. We use a machine learning approach to find an approximate optimal solution to the social planner's control problem. In addition, we present a formal proof demonstrating that the solution for the finite horizon problem converges to the solution for the infinite horizon problem. By integrating the transmission of economic fluctuations into our analysis, we consider the stochastic version of the model.

Hedging weather risk in energy markets

Fred Espen Benth, University of Oslo, Norway

With a large renewable power production, actors in the energy markets are exposed to weather risk. Various weather-related derivatives products exist for managing this risk, both traded on exchanges and in bilateral contracts. In this talk we review work on stochastic modeling of wind, solar irradiation and temperature, weather variables impacting supply and demand of power. We further analyse the risk premium when pricing weather derivatives, as well as a hedging problem for basis risk, relevant for producers and retailers in the energy market.

Optimal Investment with Intergenerational Solidarity

Luke Thomas Servat, Maastricht University, Netherlands
Joint work with: Antoon Pelsser

The Law Future Pensions (Wet Toekomst Pensioenen, WTP), adopted in 2023, adds the Netherlands to the growing list of countries whose second pension pillar is changing to a defined contribution plan. Due to the cessation of guarantees in this plan, pension funds have been given the novel task of finding an optimal *solidary* strategy, that aims to prevent so-called "fortunate" and "unfortunate" generations. This paper investigates how differences in pensions can be reduced by changing the investment strategy during the accumulation phase. The classic life-cycle does not have this solidarity feature, as it is based on a utility function that only considers its own wealth. For this reason, we adapt the utility functions such that a cohort not only looks at its own accumulated wealth, but also compares this to the wealth of the preceding cohort. The optimal investment strategy that is found as a solution to this novel problem, what we call the "intergenerational" life-cycle, deviates significantly from the classic life-cycle. We observe the "intergenerational" strategy de-risks during the periods in which consecutive cohorts are not both investing, but increases exposure during periods in which they are both accumulating. Furthermore, we observe that, due to the finite leverage and quasi-linearity, that our solution bears a strong resemblance to the "100-age" rule, which is often used in practice in the Netherlands. Finally, we conduct multiple simulations which confirm that, without any loss of the level of wealth, the pursued leveling effect of the investment strategy is indeed realized.

Inter-generational cross-subsidies in UK collective defined contribution funds

John Armstrong, King's College London, United Kingdom
Joint work with: J Dalby, C Donnelly

We will evaluate the performance of single-employer and multi-employer collective defined contribution (CDC) schemes which have been designed to be compatible with UK legislation. The single-employer scheme captures the essential features of the Royal Mail CDC scheme, which is currently the only UK CDC scheme. We find that the schemes are successful in smoothing pension outcomes while outperforming annuities, but also find that their are significant inter-generational cross-subsidies.

The cross-subsidies in the single-employer scheme are, for the most part, there by design and mirror the cross-subsidies seen in existing defined benefit schemes. The cross-subsidies in the multi-employer scheme, by contrast, arise from a discrepancy between the approximate pricing methodology implicit in the scheme design and the rigorous pricing methodology required to accurately price what is a complex derivatives contract. While these these cross-subsidies tend to cancel out over time, but in any given year they can be surprisingly large, implying that it is important to use a rigorous pricing methodology when valuing collective pension investments.

Optimal additional voluntary contribution in DC pension schemes to manage inadequacy risk

Elena Vigna, Università di Torino and Collegio Carlo Alberto, Italy
Joint work with: Henrique Ferreira Morici

In defined contribution pension schemes the member bears the investment risk and her main concern is to obtain an inadequate fund at retirement. To address inadequacy risk, flexibility is often given to the member to pay additional voluntary contributions (AVCs) into the fund. In many countries the AVC schemes allow members of the workplace pension plan to increase the amount of retirement benefits by paying extra contributions. In this paper, we define a target-based optimization problem where the member of an AVC scheme can choose at any time the investment strategy and the additional voluntary contributions to the fund. In setting the problem, the member faces a trade-off between the importance given to the stability of payments during the accumulation phase and the achievement of the desired annuity at retirement. We derive closed-form solutions via dynamic programming and prove that (i) the optimal fund never reaches the target final fund, (ii) the optimal amount invested in the risky asset is positive, and (iii) the optimal AVC is higher than the target one. We run numerical simulations to allow for different member's preferences, and perform sensitivity analyses to assess the controls' robustness.

0DTE Option Pricing

Roberto Reno, ESSEC Business School, France
Joint work with: F. Bandi, N. Fusari

The market for ultra short-tenor (zero days-to-expiry or 0DTE) options has grown exponentially over the last few years. In 2023, daily volume in 0DTEs reached over 45% of overall daily option volume. After briefly describing this exploding new market, we present a novel pricing formula designed to capture the shape of the 0DTE implied volatility surface. Pricing hinges on an Edgeworth-like expansion of the conditional characteristic function of the continuous portion of the underlying's price process. The expansion shifts probability mass from an otherwise locally Gaussian return density by adding time-varying skewness (through leverage) and time-varying kurtosis (through the volatility-of-volatility). The expansion is local in time and, therefore, naturally suited to price ultra short-tenor instruments, like 0DTEs. We document considerable (1) price and (2) hedging improvements as compared to state-of-the-art specifications. We conclude by providing suggestive results on nearly instantaneous predictability by estimating 0DTE-based return/variance risk premia.

Modern pension design by refundable income tontines

Sascha Günther, Université de Lausanne, Switzerland
Joint work with: Peter Hieber

In many countries, life or pension products include guaranteed amounts or guarantee periods, ensuring that a certain percentage of contributions is guaranteed to the policyholders. In the event of an early death in the retirement phase, a portion of the policyholder's funds may be paid as a bequest. Such a guarantee is costly and reduces the payments to survivors, but, at the same time, this feature might reduce scepticism towards tontine products from both customers and regulators. We show how such a guarantee can be added to a tontine design, without leaving any risks with the insurance provider. In a Lee-Carter mortality model, this product is compared to refundable income annuities, where payments are fully guaranteed to policyholders.

Fair Decision-Making via Counterfactual Sensitivity Analysis

Fei Huang, UNSW Sydney, Australia
Joint work with: Silvana Pesenti

This paper proposes an individual fairness criterion via counterfactual sensitivity analysis. It achieves fairness by eliminating the sensitivity of decision-making to protected attributes. Different from traditional fairness criteria, which only focus on fair machine learning tasks, this fairness criterion is applied to a two-step decision-making process, which can be potentially applied to various applications, especially in insurance and finance. The first step is a machine learning task estimating a loss random variable; the second step is for decision-making by computing a distortion risk measure of the loss random variable. The counterfactual sensitivity fairness criterion is directly applied to the final decision-making stage and ensures fair outcomes. In this paper, we use fair insurance pricing as an example for empirical analysis.

Causal insights on the spectrum of "fair" insurance tariffs

Marie-Pier Cote, Université Laval, Canada
Joint work with: O. Côté, A. Charpentier

In many jurisdictions, insurance companies are prohibited from discriminating based on some given policyholder characteristics. The more stringent regulations are now further requiring to mitigate disparate impact, in terms of profit and/or premium, or proxy discrimination with respect to protected groups. In practice, these conflicting fairness goals cannot be simultaneously achieved when the sensitive attribute is associated with the claim risk. A compromise must be made along the fairness spectrum, ranging from best-estimate (actuarially fair) premiums to corrective (demographically fair) premiums. Along that spectrum lies the aware premium, that does not discriminate directly and admits precisely the demographic disparities that are justified by causality. We propose a methodology to position a given tariff structure on the spectrum and assess its fairness outcome with respect to a given portfolio. We illustrate with high-dimensional real data from a Canadian insurance company, where the sensitive attribute is an indicator of low credit-based insurance score, whose use is prohibited in the province of Ontario. From the policyholder's perspective, premiums that are deemed fair with respect to a specific insurer's portfolio might not lead to fair market-wide premiums. Taking advantage of causal graphs, we study the impact of portfolio composition under various data-generating mechanisms with two insurers. We analyze how aware and corrective estimates from each insurer may generate a market-wide expected price – derived from a mixture of all insurers' prices, weighted by underwriting criteria – that behaves like a different fair premium family. This market-wide price is perceived by regulators and consumers, who are at the centre of fairness

Alternative technique of pricing without martingale measure

Emmanuel Lepinette, Université Paris Dauphine, France

Pricing a contingent claim is a classical problem in finance but that can be difficult in incomplete markets because, under NA, there are an infinite number of risk neutral probability measures to identify. Moreover, the minimal super-hedging price is also difficult to compute as the supremum of the expected discounted payoff over all martingale measures. Actually we show that, in discrete time, we may compute the infimum of the super-hedging prices without any no-arbitrage condition when the payoff is of the form $g(S_T)$. When g is convex, we also have an explicit and simple expression of the hedging strategy. The technique is interesting because it may be also applied to Asian or American options. Moreover, the same approach applies to models with transactions costs even if they are non convex so that they do not have dual elements characterizing a possible no-arbitrage condition.

Importance sampling for option pricing with feedforward neural networks

Aleksandar Arandjelović, WU - Vienna University of Economics and Business, Austria
Joint work with: Thorsten Rheinländer, Pavel V. Shevchenko

We study the problem of reducing the variance of Monte Carlo estimators through performing suitable changes of the sampling measure computed by feedforward neural networks. To this end, building on the concept of vector stochastic integration, we characterize the Cameron-Martin spaces of a large class of Gaussian measures induced by vector-valued continuous local martingales with deterministic covariation. We prove that feedforward neural networks enjoy, up to an isometry, the universal approximation property in these topological spaces. We then prove that sampling measures generated by feedforward neural networks can approximate the optimal sampling measure arbitrarily well. We conclude with a comprehensive numerical study pricing path-dependent European options for asset price models that incorporate factors such as changing business activity, knock-out barriers, dynamic correlations, and high-dimensional baskets.

Volatility: rough or not?

Julien Guyon, École nationale des ponts et chaussées, Institut Polytechnique de Paris, France
Joint work with: Mehdi El Amrani, Jordan Lekeufack

Rough volatility models have attracted a lot of attention since the seminal article "Volatility is rough" by Gatheral, Jaisson, and Rosenbaum (2014), who showed that these models can very parsimoniously capture some important stylized facts about volatility. Chief among them: (1) the roughness of volatility paths, and (2) the power-law term-structure of the at-the-money (ATM) skew. We reexamine these two points. While our study broadly confirms those findings, we show that (1) the roughness of volatility paths at the daily scale can also be explained by simpler non-rough Markovian models, and (2) the power-law term-structure of the ATM skew in fact fails to be valid for short maturities, where the skew does not appear to blow up. Rough volatility models, which generate such blow up, are thus inconsistent with the short-term skew. Simple non-rough models, with just one extra parameter, are shown to much better fit the whole term-structure. Our study concludes that while rough volatility is a natural, appealing, very parsimonious parametrization, at least one extra parameter is needed in order to disentangle the long-term (power-law) decay of spot-vol covariances from their short-term (non-blowing-up) behaviour — and this extra parameter precisely makes volatility paths non-rough. This talk is partly based on joint works with Jordan Lekeufack and Mehdi El Amrani.

Optimal Smooth Consumption and its Trade-Offs

Philipp Carsten Hornung, University of Copenhagen, Denmark
Joint work with: Mogens Steffensen

We investigate different ways to design smooth pension products based on solutions to optimal consumption and investment problems. The smoothness of a consumption process can be studied from both a pathwise (measured in terms of quadratic variation) and a pointwise (measured in terms of variance) point of view, and we conclude that introducing one type of smoothing does not necessarily improve the other type of smoothing. Thus, care must be taken when designing smooth pension products. Focusing on pathwise smoothness without disregarding pointwise smoothness, we provide both a qualitative and a quantitative discussion of the trade-offs involved. In the qualitative discussion, we find that to increase smoothness, it is necessary to reduce the starting value, the drift of consumption, or the level of terminal wealth. For the quantitative discussion, we set up an optimal consumption and investment problem, where the first control is the proportion of wealth invested into the risky asset, but the second control is not the consumption process itself. Instead, we use the drift and volatility of consumption as controls. The objective is to minimize the quadratic distance to a target drift and volatility while introducing a penalty for the volatility. We find explicit solutions to this problem using classic dynamic programming methods and use them to study the three trade-offs theoretically and numerically. All three approaches result in both pointwise and pathwise smoothing compared to the target, but reducing the drift yields better pointwise smoothing for similar levels of pathwise smoothing.

Weather Shocks and Crop Abandonment: Theory and Evidence from Zambia

Nixon Shingai Chekenya, Texas Tech University, United States

Crop abandonment is when farmers decide not to harvest their previously planted crop. There is limited but emerging literature on crop abandonment or failure predominantly examining weather and crop failure rates. Consistent with these existing scant studies, it is not immediately clear to what extent historical relationships can be extrapolated in the long run under climate change. This paper seeks to improve our understanding of determinants of crop abandonment decisions in Zambia for crop production at subnational level. The paper seeks to improve our understanding of heterogeneities in crop abandonment decisions in Zambia for maize, rice, soybean, sorghum, cassava and millet at provincial, district and town level and how it is impacted by other risk sources (such as crop and storage prices) and risk management strategies (like participation in index-based insurance program).

Risk measurements for blockchain mining pools and crypto asset management

Zixin Feng, Macquarie University, Australia
Joint work with: Zhuo Jin

In this paper, we study the optimal decision-making problem of miners and pool managers in blockchain pooled mining. To the best of our knowledge, risk measures are first introduced into the activity of blockchain mining, unlike the concept of utilities that are abundant in the existing literature. It is also pointed out that under this concept, miners prefer to join mining pools for mining rather than solo mining. Afterwards, we build a risk model with the goal of minimizing risk measures of miners and pool managers, trying to analyze their behaviors in equilibrium and the resulting consequences. In the quantitative illustration, we show the trend of the global hash rate, the optimal fee, and the growth rate of the mining pool with some important variables.

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

Javier Garcia Gonzalez, Tilburg University, Netherlands
Joint work with: Anne Balter and Nikolaus Schweizer

This paper explores the potential of leveraged Exchange Traded Funds (LETFs) for long-term investors and lifecycle portfolios. Conventionally, 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: secondary risks associated to LETFs make it worthwhile only if the investor is sufficiently risk-tolerant. We also solve static and dynamic portfolio optimization problems taking leverage costs into account. We show that the optimal leverage target decreases with leverage costs, and find closed form expressions for welfare gains of relaxing leverage constraints and welfare losses related to the leverage costs in comparison to an idealized Merton world.

Multi-Agent Deep Reinforcement Learning for High-Frequency Multi-Market Making

Pankaj Kumar, Jheronimus Academy of Data Science, Netherlands

High-frequency multi-market making is a liquidity-providing strategy that exercises cross-market latency arbitrage in order to simultaneously post multiple bids and asks in a fragmented market for a security or co-related securities, while maintaining a relatively low net position. By exploiting price discrepancies between

markets, the strategy earns profit from the bid-ask spread for every trade against the risk of inventory, liquidity and adverse selection. We develop a multi-market simulation framework built over empirically verified heterogeneous agents, with a realistic market design and matching engine. We use it to design high-frequency market making agents based on deep attention recurrent Q-network architecture a with spatial and temporal attention module, to efficiently capture the non-linear features of the order book. We train heterogeneous market making agents, trading in the presence of other agents, with a simulation framework that employs independent Q-learning in a multi-agent deep reinforcement learning setting. We demonstrate the effectiveness of our agents in relation to traditional deep architecture and benchmark strategies using Deep Hawkes processes. We investigate the effect of latency and different market ecology on the market quality. We also reproduce a number of stylised facts in order to validate the simulation framework.

Solving Dynamic Portfolio and Consumption Problems by Going Forward in Time

Yixuan Ma, Maastricht university, Netherlands
Joint work with: Paulo Rodrigues, Peter Schotman

The standard approach to solving dynamic portfolio and consumption problems numerically uses backward induction, which complicates the solution if decisions at time t depend on past decisions. In contrast, our solution algorithm goes forward in time. We use the insight that the main task in solving dynamic optimization problems consists of finding policy functions that use the current value of state variables as inputs and give the optimal decisions as outputs. Instead of assuming a functional form for these policy functions, we use a neural network for the estimation of the functions.

Numerical valuation of swing options: discrete exercise rights

Mustapha Regragui, Ghent University, Belgium
Joint work with: FE. Benth, KJ. In ’t Hout, M. Vanmaele

Swing options are widely traded derivative contracts in the energy markets, especially the electricity market. They give the holder the right to, dynamically, buy electricity at a predetermined, fixed price and, hence, reducing exposure to strong price fluctuations. There is a constraint on the amount that can be bought by the holder at each exercise date and also during the whole contract period. In our research, we are interested in the numerical valuation of swing options. The energy price is modelled by a two factor model in order to encapsulate its mean-reversion feature. In addition, we take into the account the occurrence of price spikes as well as the possibility of negative prices as in [1]. We focus on swing options with discrete and fixed-time exercise rights, which lead us to the study of multiple parabolic partial integro-differential equations. We develop and investigate an effective finite difference approach to solve these equations numerically.

1- Eriksson, M., Lempa, J. and Nilssen, T. K., Swing options in commodity markets: a multidimensional Lévy diffusion model, Mathematical Methods of Operations Research 79, p. 31-67 (2013).

HJB equation for maximization of wealth under insider trading

Iván de Jesús Rodríguez Durán, Centro de Investigación en Matemáticas, Mexico
Joint work with: Liliana Peralta, Jorge A. León

In this paper, we combine the techniques of enlargement of filtrations and stochastic control theory to establish an extension of the verification theorem, where the coefficients of the stochastic controlled equation are adapted to the underlying filtration and the controls are adapted to a bigger filtration G than the one generated by the corresponding Brownian motion B. Using the forward integral defined by Russo and Vallois, we show that there is a G-adapted optimal control with respect to a certain cost functional if and only if the Brownian motion B is a G-semimartingale. The extended verification theorem allows us to study a

financial market with an insider in order to take advantage of the extra information that the insider has from the beginning. Finally, we consider two examples throughout the extended verification theorem. These problems appear in financial markets with an insider.

Shrinking the Covariance Matrix: A Portfolio Perspective

Rodolphe Vanderveken, UCLouvain, Belgium
Joint work with: Nathan Lassance, Frédéric Vrins

Estimating the covariance matrix is a central problem in portfolio selection. The foundational shrinkage methodologies developed by Ledoit and Wolf (2004, 2017) suffer from two drawbacks: they are not designed to optimize out-of-sample portfolio performance and do not account for estimation errors in the means. In this paper, we propose a novel shrinkage covariance matrix estimator that addresses these two drawbacks. Specifically, we calibrate the shrinkage intensities in linear and nonlinear shrinkage estimators so that they maximize the expected out-of-sample portfolio performance. We find that this alternative calibration results in higher shrinkage intensities relative to the traditional approach and delivers a superior out-of-sample portfolio performance. Overall, our methodology is a one-step approach that estimates the covariance matrix and the optimal portfolio at the same time, which delivers large economic gains relative to the conventional two-step scheme.

Longevity swaps for longevity risk management in life insurance products

Nixon Shingai Chekenya, Texas Tech University, United States
Joint work with: Canicio Dzingirai

The life insurance industry has been exposed to high levels of longevity risk born from the mismatch between realized mortality trends and anticipated forecast. Annuity providers are exposed to extended periods of annuity payments. There are no immediate instruments in the market to counter the risk directly. This paper aims to develop appropriate instruments for hedging longevity risk and providing an insight on how existing products can be tailor-made to effectively immunize portfolios consisting of life insurance using a cointegration vector error correction model with regime-switching (RS-VECM), which enables both short-term fluctuations, through the autoregressive structure [AR(1)] and long-run equilibria using a cointegration relationship. The authors also develop synthetic products that can be used to effectively hedge longevity risk faced by life insurance and annuity providers who actively hold portfolios of life insurance products. Models are derived using South African data. The authors also derive closed-form expressions for hedge ratios associated with synthetic products written on life insurance contracts as this will provide a natural way of immunizing the associated portfolios. The authors further show how to address the current liquidity challenges in the longevity market by devising longevity swaps and develop pricing and hedging algorithms for longevity-linked securities. The use of a cointergrating relationship improves the model fitting process, as all the VECMs and RS-VECMs yield greater criteria values than their vector autoregressive model (VAR) and regime-switching vector autoregressive model (RS-VAR) counterpart's, even though there are accruing parameters involved.

On the Carbon Tax in Golosov et al.'s 2014 Dynamic Stochastic General Equilibrium Central Planning Model

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This work presents a comprehensive analytical solution to Golosov et al.'s 2014 optimal control formulation of the carbon tax problem within a central planning framework. While the original paper focused solely on solving the problem based on first-order necessary conditions, our approach involves deriving the actual

value function. This not only enhances rigour and completeness but also provides direct access to the carbon tax as the derivative of the value function (adjusted for the Lagrangian constraints) with respect to the carbon stock in the atmosphere. In contrast, the carbon tax in Golosov et al.'s work is only implicitly inferred by comparing two setups: a central planning problem, as explored in our study, and a decentralized equilibrium setup. The paper concludes with a numerical sensitivity analysis.

Probabilistic Scoring for Unbalanced Multi-Class Classifiers: Enhancing Calibration with Nested Dichotomies

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In multi-class prediction, calibration is essential for accurately interpreting predicted scores as probabilities, thereby expanding the classification task beyond label prediction. Calibration metrics and "post-hoc" calibration techniques, originally designed for binary problems, have been adapted for multi-class contexts; however, they still face challenges, especially in unbalanced situations with underrepresented classes. To address these issues, we propose using nested dichotomy algorithms. The multi-class problems is simplified, decomposed into binary ones in a tree-like structure, allowing for a stronger emphasis on minority classes. Through experiments using simulated unbalanced data, we will compare the performance and calibration of nested dichotomies versus multi-class models, assessing the effects of post-calibration techniques. Finally, we will apply this methodology to real insurance data for race prediction, which includes minority groups, in accordance with Colorado legislation SB21-169.

Life cycle consumption and portfolio choice under real interest rate risk

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We study the implications of real interest rate risk in a realistically calibrated life cycle model. Optimal consumption-investment decisions differ with both the level of the interest rate and its volatility. Higher interest rates lead to higher consumption and lower stock investments. Ignoring the time-varying nature of real interest rates leads to suboptimal consumption-investment decisions, and ultimately, welfare losses. Extended periods of low interest rates, such as in the recent past, can lead to substantial welfare losses, even when behaving optimally.

Metamodeling Climate Trajectories Using Neural Networks

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Climate science heavily relies on large-scale models, such as those in the Coupled Model Intercomparison Project (CMIP6), which integrate complex physical, chemical, and biological processes to simulate past, present, and future climate scenarios. CMIP6, for instance, involves dozens of models and hundreds of simulations, each designed to capture different aspects of the Earth's climate system. However, the use of such large models comes with significant computational burdens, particularly as the number of state variables increases, leading to what is commonly referred to as the "curse of dimensionality."

In response, a wide range of simplified climate models aims to capture the essential dynamics of climate systems while reducing computational complexity. For example, FaIR uses four state variables for climate boxes and three for temperatures. Despite their reduced complexity, these models --basically a set of Ordinary Differential Equations -- still face limitations in their numerical resolution, especially under uncertainties, as the number of grid points needed to calculate policy functions increases exponentially with the number of state variables.

This paper proposes the use of ReLU (Rectified Linear Unit) neural networks as an efficient tool to address these computational challenges by avoiding solving ODEs. Specifically, we propose an exponential parameterization of emission trajectories, which is particularly well-suited for approximating emission pathways stabilize over time (they tend to a limit representing a long-term equilibrium). Any function converging to zero at infinity can be decomposed into an exponential form (This is a well-known result of Ch. H. Müntz at 1914 and then studied by Laurent Schwartz at 1943). Economically, this also makes sense as Integrated Assessment Models (IAMs) such as DICE (Dynamic Integrated Climate Economic model) predict that carbon emissions asymptotically stabilize to zero through long term energy efficiency and recent SSPs (Shared Socio-economic Pathway) projections extending to 2500 are coherent with this prediction for emission trajectories. By leveraging this parameterization, we aim to approximate key climate trajectories (especially our QoI (Quantify of Interest): near-surface air temperature trajectory) with neural networks. Our approach decomposes the emission trajectories into Müntz coefficients and transforms the time domain to allow for a detailed regularity properties study of our QoI. Good regularity properties of our climate variables trajectories allows us to approximate them with neural network ensuring the accuracy and robustness of the approximation. This approach is supported by ReLU neural network convergence analysis research of Dmitry Yarotsky in 2017.

Our implementation involves three main steps: first, decomposing emission pathways (e.g. SSPs) into Muntz coefficients; second, generating temperature trajectory datasets based on these coefficients; and finally, train a ReLU neural network with these datasets. Once trained, our neural network is a powerful tool for (1) efficient evaluation of temperature trajectories and (2) sensitivity analysis of our QoI to emission pathways. Sensitivity analysis will provide valuable insights for emission pathway mitigation strategies in the context of climate change. Moreover, the methodology we propose is not limited to climate modeling and can be extended to a wide range of other high-dimensional problems.

A numerical solution for European option pricing under 2-dimensional jump-diffusion processes

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A numerical approach for approximating the value of European options will be presented, assuming that the dynamics of the underlying asset prices are described by a 2-dimensional jump-diffusion process. Following [1], the jump component is obtained by subordination of a 2-dimensional Brownian motion with a 1-dimensional tempered stable subordinator, as described in [2]. This yields an infinite activity process and, therefore, gives rise to an integral of a singular function in the PIDE (Partial-Integro-Differential equation) that holds for the option value function. The Variance Gamma and the Normal Inverse Gamma processes are the most famous special cases of this type of process.

Using the method of lines for solving the PIDE, the numerical scheme is divided into two general steps: the spatial discretization, in which the (spatial) integral-differential operator is replaced with a finite-difference version, converting the PIDE to a system of linear ODEs, and next the temporal discretization, in which this system is numerically solved by a suitable time-stepping method.

A special feature of the numerical approach under consideration, that is inspired by [3] and [4], is the fact that jumps smaller than a given threshold are replaced by a diffusive term. This makes it possible to remove the singularity from the integral term, and hence, to resort in principle to well-known numerical schemes for finite activity Lévy processes. Furthermore, the integral term in the PIDE corresponds to a dense matrix in the system of linear ODEs. To avoid the inversion of this matrix, a second-order IMEX (implicit-explicit) time-stepping method is proposed, which allows for an efficient evaluation by FFT and interpolation.

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Reinforcement Learning for Actuarial Credibility, with Extensions

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Joint work with: David Landriault and Bin Li

This paper applies reinforcement learning techniques to the actuarial problem of determining a credibility weighting for claims data. We demonstrate that reinforcement learning (RL) based approaches, including both RecurrentPPO and DQN, outperform classical credibility methods, despite being restricted to a subclass of estimators and without the need for a Bayesian prior. The algorithm provides an assumption free way to determine the best credibility action given claims information and its performance over traditional methods is demonstrated in multiple simulation studies including cases with non Markovian drivers for claims.

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