AFMathConf 2024

15th Actuarial and Financial Mathematics Conference

Interplay between Finance and Insurance

AG Campus, Brussels, 5-6 February 2024

Sponsors

Table of Contents

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

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Programme Monday 5 February

09:00 – 09:20	Registration and welcome coffee
09:20 – 09:30	Welcome
	Chair: Hansjoerg Albrecher
09:30 – 10:15	INVITED SPEAKER – Séverine Arnold, University of Lausanne, Switzerland **Subsidising inclusive insurance to reduce poverty**
10:15 – 10:45	CONTRIBUTED TALK – Gero Junike, Carl von Ossietzky University, Germany **Empirical and theoretical analysis of profit and loss allocations**
10:45 – 11:15	Coffee break
	Chair: Jan Dhaene
11:15 – 12:00	INVITED SPEAKER – Christian Robert, ISFA, Université Lyon 1, and ENSAE, IPP, France **Conditional expectation given the sum when variables have regularly varying densities**
12:00 – 12:30	CONTRIBUTED TALK – Alessandro Mutti, Politecnico di Torino, Italy **Symmetric Bernoulli distributions and minimal dependence copulas**
	Chair: Ann De Schepper
12:30 – 13:00	Poster storm session
13:00 – 14:30	Sandwich lunch combined with poster session
	Chair: Steven Vanduffel
14:30 – 15:15	INVITED SPEAKER – Manuel Rach, University of St. Gallen, Switzerland **Stochastic dominance in retirement plans**
15:15 – 15:45	CONTRIBUTED TALK – Matteo Buttarazzi, La Sapienza University, Italy **Optimal annuitization and bequest motives**
15:45 – 16:15	Coffee break
	Chair: Michel Vellekoop
16:15 – 16:45	CONTRIBUTED TALK – Julie Bjørner Søe, University of Copenhagen, Denmark **What is the value of the annuity market?**
16:45 – 17:30	INVITED SPEAKER – Anne Balter, Tilburg University, Netherlands **Systematic Longevity Risk: The Willingness to Pay**
18:30 – 21:30	Conference Dinner at University Foundation

Programme Tuesday 6 February

08:30 – 09:00	Registration
	Chair: Tahir Choulli
09:00 – 09:45	INVITED SPEAKER – Fang Fang, TU Delft, Netherlands **A Dimension-Reduced Cosine-Expansion Method for Solving Multivariate Expectations**
09:45 – 10:15	CONTRIBUTED TALK – Yevhen Havrylenko, University of Copenhagen, Denmark **Value-at-risk constrained portfolios in incomplete markets: a dynamic programming approach to Heston's model**
10:15 – 10:45	Coffee break
	Chair: Ludger Ruschendorf
10:45 – 11:30	INVITED SPEAKER – Thorsten Schmidt, University of Freiburg, Germany **Insurance Finance Arbitrage**
11:30 – 12:00	CONTRIBUTED TALK – Josha Arne-Pieter Dekker, University of Amsterdam, Netherlands **Optimal Stopping with Randomly Arriving Opportunities**
12:00 – 13:00	Sandwich lunch combined with poster session
	Chair: Monique Jeanblanc
13:00 – 13:45	INVITED SPEAKER – Peter Tankov, ENSAE Paris, France **Asset pricing under transition scenario uncertainty**
13:45 – 14:15	CONTRIBUTED TALK – Morten Wilke, Vrije Universiteit Brussel, Belgium **Optimal Payoffs under KMM Preferences**
14:15 – 14:45	Coffee break
	Chair: Carole Bernard
14:45 – 15:30	INVITED SPEAKER – Paolo Giudici, University of Pavia, Italy **Sustainable, Accurate, Fair and Explainable AI in finance**
15:30 – 16:00	CONTRIBUTED TALK – Corina Birghila, Otto-von-Guericke University Magdeburg, Germany **Portfolio selection with ambiguity aversion and model ambiguity**
16:00 – 16:15	Closing

Programme Poster session

Jean-Loup Dupret
Impact of rough stochastic volatility models on long-term life insurance pricing

Arnaud Germain
Optimal securitization of SME loans: the selection problem

Pankaj Kumar
Deep Hawkes Process for High-Frequency Market Making

Kaitlyn Louth
Bayesian Modelling and Statistical Machine Learning for Morbidity Rate Prediction

Tak Wa Ng
Efficient Collective Investment with Limited Expected Loss: Pareto-optimal Wealth Sharing and Risk Allocation

Felix Sachse
State space decomposition and classification of term structure shapes in the two-factor Vasicek model

Saeid Safarveisi
Catastrophe Bond Pricing Under Renewal Process

Konstantinos Stefanakis
Equilibrium returns in markets with price impact and frictions

Subsidising Inclusive Insurance to Reduce Poverty

Séverine Arnold, University of Lausanne, Switzerland
Joint work with: José Miguel Flores-Contró, Kira Henshaw, Sooie-Hoe Loke, Corina Constantinescu

In this article, we assess the benefits of coordination and partnerships between governments and private insurers, and provide further evidence for microinsurance products as powerful and cost-effective tools for achieving poverty reduction. To explore these ideas, we model the capital of a household from a ruin-theoretic perspective to measure the impact of microinsurance on poverty dynamics and the governmental cost of social protection. We analyse the model under four frameworks: uninsured, insured (without subsidies), insured with subsidised constant premiums and insured with subsidised flexible premiums. Although insurance alone (without subsidies) may not be sufficient to reduce the likelihood of falling into the area of poverty for specific groups of households, since premium payments constrain their capital growth, our analysis suggests that subsidised schemes can provide maximum social benefits while reducing governmental costs.

Empirical and theoretical analysis of profit and loss allocations

Gero Junike, Carl von Ossietzky University, Germany
Joint work with: Marcus Christiansen, Solveig Flaig, Hauke Stier

The decomposition of the investment profit and loss (p&l) for each business year into different risk factors (e.g., interest rates, credit spreads, foreign exchange rate etc.) is a task that is regulatory required, e.g., by Solvency 2. Three different decompositions are prevalent: one-at-a-time (OAT), sequential updating (SU) and average sequential updating (ASU) decompositions. The SU and the ASU decompositions explain the p&l fully, i.e. are exact. However, the OAT decomposition generates some unexplained p&l. The SU decomposition depends on the update order of the risk factors, i.e., if there are d risk factors, there are $d!$ SU decompositions. The ASU decomposition is defined by the average over all $d!$ SU decompositions. The three decompositions can be defined on different sub-intervals using annually, quarterly, monthly, weekly or daily data. In this talk, using financial market data from 2003 till 2022, we empirically quantify: the unexplained p&l of the OAT decomposition; the dependence of the SU decomposition on the update order; and how much the three decomposition principles depend on the size of the sub-intervals. We will see that the ASU decomposition is the most useful decomposition in practice. In the second part of the talk, we derive a generalized Ito's formula. We obtain a new family of decompositions from the generalized Ito's formula, called Ito decomposition, and we show that this family contains the OAT, SU and ASU decompositions as limiting cases. We show that there is only one Ito decomposition, which satisfies three axioms: exactness, normalization and symmetry. This Ito decomposition is called IASU decomposition and is the limiting case of the ASU decomposition. The IASU and ASU decomposition scale like $O(d!)$, i.e., they suffer from the curse of dimensionality. In the limiting case, we show that it is possible to break the curse of dimensionality: asymptotically, the ASU decomposition can be approximated by just two SU decompositions if the risk factors do not have simultaneous jumps. Therefore, analyzing the limit of the ASU decomposition has also practical relevance.

Conditional expectation given the sum when variables have regularly varying densities

Christian Robert, ISFA, Université Lyon 1, and ENSAE, IPP, France
Joint work with: Michel Denuit, Patricia Ortega Jimenez

Stochastic monotonicity of two independent random variables X and Y given the value of their sum $S = X + Y$ has been linked to log-concave densities since Efron (1965). However, the log-concavity assumption is not realistic in some applications because it excludes heavy-tailed distributions. This paper considers random variables with regularly varying densities to illustrate how heavy tails can lead to a non-monotonic behavior for the conditional expectation $m_X(s) = E[X|S = s]$, which turns out to be problematic in signal processing or in risk sharing, for instance. This paper first aims to identify situations where a non-monotonic behavior appears according to the tail-heaviness of X and Y. The analysis is then extended to zero-augmented probability distributions. Consequences for signal processing and risk sharing are discussed. Many numerical examples illustrate the results.

Symmetric Bernoulli distributions and minimal dependence copulas

Alessandro Mutti, Politecnico di Torino, Italy
Joint work with: P. Semeraro

The key result of this paper is to find all the joint distributions of random vectors whose sums $S = X_1 + \ldots + X_d$ are minimal in convex order in the class of symmetric Bernoulli distributions. The minimal convex sums distributions are known to be strongly negatively dependent. Beyond their interest per se, these results enable us to explore negative dependence within the class of copulas. In fact, there are two classes of copulas that can be built from multivariate symmetric Bernoulli distributions: the extremal mixture copulas, and the FGM copulas. We study the extremal negative dependence structure of the copulas corresponding to symmetric Bernoulli vectors with minimal convex sums and we explicitly find a class of minimal dependence copulas. Our main results stem from the geometric and algebraic representations of multivariate symmetric Bernoulli distributions, which effectively encode several of their statistical properties.

Stochastic dominance in retirement plans

Manuel Rach, University of St. Gallen, Switzerland
Joint work with: An Chen, Alfred Mueller

Retirement income tontines are retirement plans where benefits are obtained from the inheritance of non-surviving participants. This paper analyzes stochastic dominance relations between tontines and annuities. In the presence of risk loadings and/or subjective probabilities underestimating the insurer's pricing probabilities, we find the benefits of a properly designed tontine to dominate the benefits of a constant annuity in the almost first order stochastic dominance (AFSD) sense as defined by Leshno and Levy (2002). In particular, we show that this AFSD converges to first order stochastic dominance as the pool size in the tontine tends to infinity.

Optimal annuitization and bequest motives

Matteo Buttarazzi, La Sapienza University, Italy
Joint work with: Tiziano De Angelis, Gabriele Stabile

Timing the annuitization decision has critical economic implications because it directly affects how well-prepared individuals are to provide consumption in their old age. This decision hinges on various risk factors such as market risk, longevity risk, potential future needs of liquid funds and bequest motives. Building on Yaari's pioneering work [1], which suggested that individuals without bequest motives should convert all their

retirement savings into annuities, numerous studies have explored the annuitization choice within the "all or nothing" institutional framework, where immediate lifetime annuities are purchased just at one point in time.

In this paper, we investigate the effect of bequest motives on the annuitization decision for a retired individual who maximizes the market value of future cash flows. From a mathematical point of view, the problem is formulated as an optimal stopping problem. The individual faces a choice between investing in the financial market or converting his capital into periodic income through an annuity. The attractiveness of the annuity depends on market conditions and the retiree's health status. To account for the unpredictable nature of health conditions, we adopt a stochastic mortality force framework. Initially, the individual enjoys optimal health, but at an unforeseen point, his health deteriorates, triggering an increase in the mortality risk. In this context, the individual must determine when (if ever) to purchase the annuity.

[1] M.E. Yaari, Uncertain lifetime, life insurance and the theory of consumer. Rev. Econ. Stud. 32 (1965), pp. 137–150.

What is the value of the annuity market?

Julie Bjørner Søe, University of Copenhagen, Denmark
Joint work with: Mogens Steffensen

In the decumulation phase of a pension plan, consumption depends on the level of annuitization. We measure the welfare loss of an individual with a demand for annuitization if he has no access to annuitization or, equivalently, does not use such access. Unlike earlier studies of the value of the annuity option, both individuals with and without access to annuitization, respectively, are offered complete flexibility in the consumption/payout profile. In that sense, we assume that the financial institutions (are allowed to) design the best possible products in the two regimes, with and without annuitization. We find for realistic parameters that a patient individual with time-additive preferences loses 22% of wealth upon retirement if not annuitizing. Sensitivity studies show that the relative loss decreases with a higher interest rate, a higher market price of financial risk, a higher market price of mortality risk, more certainty in the lifetime distribution, and a lower elasticity of intertemporal substitution. Further, we analyze a suboptimal bank product based on conditional expected residual lifetime.

Systematic Longevity Risk: The Willingness to Pay

Anne Balter, Tilburg University, Netherlands
Joint work with: Malene Kallestrup-Lamb, Mathias Plovst

Increasing life expectancy has led to a global transition in pension systems towards more variable products in which risk is explicitly borne by the participants, necessitating a thorough understanding of longevity risk. This risk is explicitly transferred to policyholders contrasting with earlier implied hedges. Our goal is to quantify longevity risk through its impact on welfare, i.e., the willingness to pay. Longevity risk can be categorized into idiosyncratic and systematic, with the latter, representing changes in life tables, being the focus of our study. The risk is determined as life expectancy changes over time beyond the already incorporated projected increase. Addressing the gap in quantifying systematic longevity risk, we introduce a multiple-horizon approach in which we calculate the realized “unexpected” deviations in best estimated survival rates due to arrival of new observations in the mortality model. Our findings unveil that the willingness to pay to avoid the systematic longevity risk, i.e., the risk premium required to bear this risk, ranges from 6%-25% depending on the horizon and risk preferences. We conduct sensitivity analyses, exploring cross-country variations and gender differentials, contributing novel insights to the literature on the size of systematic longevity risk.

A Dimension-Reduced Cosine-Expansion Method for Solving Multivariate Expectations

Fang Fang, TU Delft, Netherlands
Joint work with: Marnix Brands, Xiaoyu Shen

The Fourier-cosine expansion method for density recovery and option pricing, or the COS method in short, was first proposed by Fang and Oosterlee in [1] to price European options, and since then, it has been widely used in the field of financial mathematics. For the purpose of option valuation, extensions have been made, for example, to pricing Barrier and American options [2, 3] and Asian options [4] as well as to the 2D-COS method [5]; For the purpose of risk quantification, it has been applied and adjusted to fast computing measures like Value-at-Risk (VaR) and Expected Shortfall (ES) [6] and lately to the calculation of Euler allocation measures [7]; In the field of insurance risk theory, the COS method has been applied in the recovery of various density functions, such as the ruin probability [8], the discounted density function of the deficit at ruin [9], the finite time ruin probabilities [10], etc. In this talk, we will present our recent research work on the COS method for efficient calculation of multivariate expectations. Multivariate expectation is the mathematical problem common to various fields related to the probability theory. Very often there exists no analytical solution and one has to rely on numerical methods. Our key insight is that, in many applications in finance, the original multivariate expectation problem can be reformulated as a univariate problem which is easier to solve in the Fourier domain. To be more specific, the original problem can be transformed to solving the characteristic function (ch.f.) of the combined dynamics of the multiple random variables involved. To compute this ch.f., we developed a dimension-reduced cosine-expansion, via applying Carnonic Polyadic Decomposition (CPD) to the Fourier-cosine expansion coefficient tensor. This method is thus named COS-CPD method. It avoids the curse-of-dimension in the on-the-fly calculations and is tested to be very efficient and stable. We will illustrate the application of the COS-CPD method using the example of Potential Future Exposure (PFE) and XVA calculations for netting pools of Over-the-Counter (OTC) derivatives.

Value-at-risk constrained portfolios in incomplete markets: a dynamic programming approach to Heston's model

Yevhen Havrylenko, University of Copenhagen, Denmark
Joint work with: M. Escobar-Anel, R. Zagst

This talk is centered on dynamic portfolio optimization with terminal-wealth constraints. We start with a brief overview of the seminal paper H. Kraft and M. Steffensen (2013), in which the authors generalize the dynamic programming approach to optimal-investment problems with terminal-wealth constraints in a complete Black-Scholes market. Building on that, we extend the dynamic programming approach to constrained portfolio optimization problems in an incomplete financial market, where the stock price follows the Heston stochastic volatility model. We demonstrate that the value function in the constrained problem can be represented as an expected modified utility of a vega-neutral financial derivative on the optimal wealth in the unconstrained problem. Furthermore, we show how the optimal wealth and the optimal investment strategy in the constrained problem are linked to the optimal wealth and the optimal investment strategy in the unconstrained problem. We show the details using the example of a power-utility maximizing investor with a Value-at-Risk constraint on terminal wealth. At the end of the talk, we show the results of our numerical studies and highlight the potential of our methodology for solving other utility-maximization problems with terminal-wealth constraints in incomplete markets.

Insurance Finance Arbitrage

Thorsten Schmidt, University of Freiburg, Germany
Joint work with: Katharina Oberpriller and Moritz Ritter

In most cases, insurance contracts are linked to the financial markets, such as through interest rates or equity-linked insurance products. To motivate an evaluation rule in these hybrid markets, Artzner et al. (2022) introduced the notion of insurance-finance arbitrage. In this paper we extend their setting by incorporating model uncertainty. To this end, we allow statistical uncertainty in the underlying dynamics to be represented by a set of priors P. Within this framework we introduce the notion of robust asymptotic insurance-finance arbitrage and characterize the absence of such strategies in terms of the concept of QP-evaluations. This is a nonlinear two-step evaluation which guarantees no robust asymptotic insurance-finance arbitrage. Moreover, the QP-evaluation dominates all two-step evaluations as long as we agree on the set of priors P which shows that those two-step evaluations do not allow for robust asymptotic insurance-finance arbitrages. Furthermore, we introduce a doubly stochastic model under uncertainty for surrender and survival. In this setting, we describe conditional dependence by means of copulas and illustrate how the QP-evaluation can be used for the pricing of hybrid insurance products.

Optimal Stopping with Randomly Arriving Opportunities

Josha Arne-Pieter Dekker, University of Amsterdam, Netherlands
Joint work with: Roger J.A. Laeven, John G.M. Schoenmakers, Michel H. Vellekoop

Motivated by asset-liquidity spirals, we analyze general optimal stopping problems in which opportunities to exercise an option arrive randomly, and where the occurrence of the exercise opportunities and the option's underlying asset price processes may be interrelated. Such problems occur naturally in applications with market frictions and are thus relevant for financial applications.

To date, a few papers have studied optimal stopping problems where the stopping opportunities are restricted to random times, and these are typically generated by an independent Poisson process. The development of numerical methods for these problems is still ongoing and we are not aware of a numerical method that deals with more intricate arrival processes, such as processes that depend on the underlying asset prices.

In this work, we provide such numerical methods, under the assumption of Markovian dynamics. The pivotal element of our approach is the use of random rather than deterministic time scales, which brings important computational advantages.

This change of perspective allows us to introduce three algorithms that are adapted from algorithms from the Bermudan option pricing literature: we extend the Longstaff-Schwartz algorithm, the policy iteration algorithm and the Andersen-Broadie dual method to be able to use them for optimal stopping problems with randomly arriving opportunities. We determine conditions for the validity of our algorithms and their convergence.

The efficiency of our methods and the relevance of randomly arriving opportunities are illustrated in a few examples, among which a variant of a benchmark example: the Bermudan max-call contract.

Asset pricing under transition scenario uncertainty

Peter Tankov, ENSAE Paris, France
Joint work with: Maria Flora, Theo Le Guenedal

Risks and opportunities related to environmental transition are usually evaluated through the use of scenarios, produced and maintained by international bodies such as the International Energy Agency or the Network for Greening the Financial System (NGFS). This approach assumes perfect knowledge of the scenario by the agent, but in reality, scenario uncertainty is an important obstacle for making optimal investment or divestment decisions. In this talk we present two studies of the impact of transition scenario uncertainty on the optimal financial decision-making and asset pricing.

In the first study, we develop a real-options approach to evaluate assets and potential investment projects under dynamic climate transition scenario uncertainty. We use off-the-shelf Integrated Assessment Model (IAM) scenarios and assume that the economic agent acquires the information about the scenario progressively by observing a signal, such as the carbon price or the greenhouse gas emissions. The problem of valuing an investment is formulated as an American option pricing problem, where the optimal exercise time corresponds to the time of entering a potential investment project or the time of selling a potentially stranded asset. To illustrate our approach, we employ representative scenarios from the NGFS scenario database in two energy-related examples: the divestment decision from a coal-fired power plant without Carbon Capture and Storage (CCS) technology and the potential investment into a green coal-fired power plant with CCS.

In the second study, we develop a structural model for pricing a defaultable bond issued by a company subject to climate transition risk. We assume that the magnitude of the transition risk impacts depends on a transition scenario, which is initially unknown but is progressively revealed through the observation of the carbon price trajectory. The bond price, credit spread and optimal default/restructuring thresholds are then expressed as function of the firm's revenue level and the carbon price. Numerical implementation of the resulting formulas is discussed and illustrated using real data. Our results show that under transition scenario uncertainty, carbon price adjustments are more likely to trigger a default than when the true scenario is known because after each adjustment the more environmentally stringent scenario becomes more likely. We also find that faster discovery of scenario information leads to higher credit spreads since better information allows the shareholders to optimize the timing of default, increasing the value of default option and decreasing the bond price.

Optimal Payoffs under KMM Preferences

Morten Wilke, Vrije Universiteit Brussel, Belgium
Joint work with: An Chen (Ulm University), Steven Vanduffel (Vrije Universiteit Brussel)

We study optimal payoff choice for an investor in a one-period model under KMM preferences proposed by Klibanoff et al. (2005). In contrast, to the existing literature on optimal asset allocation for a KMM investor in a one-period model, we also allow payoffs that are non-linear in the stock price. Our contribution is threefold. First, we characterize and derive the optimal payoff under KMM preferences. Second, we demonstrate that a KMM investor solves an equivalent problem to an investor under classical subjective expected utility (CSEU) with adjusted second-order beliefs. Third, in a setting of a log-normal market asset under drift and volatility uncertainty, we reveal that ambiguity leads to optimal payoffs that are no longer necessarily long in the market asset.

Sustainable, Accurate, Fair and Explainable AI in finance

Paolo Giudici, University of Pavia, Italy
Joint work with: Emanuela Raffinetti

We present a set of statistical metrics that can be employed to assess the risks of AI applications in finance and to develop an AI risk management model that can be used as a monitoring tool. The metrics are based on the regulatory requirements recently proposed in the European AI Act, which we propose to combine in a set of integrated statistical scores, all based on the extension of the well known Lorenz curve: from the measurement of concentration in population incomes to the measurement of concentration in machine learning predictions.

The statistical measures we propose concern: Sustainability, which refers to the resilience of the AI model output to extreme events and to cyber attacks; Accuracy, which refers to the predictive accuracy of the model; Fairness, which refers to the absence of biases towards specific population groups, induced by the AI output; Explainability, which refers to the capability of the model output to be oversight by humans, particularly in its driving causes.

Portfolio selection with ambiguity aversion and model ambiguity

Corina Birghila, Otto-von-Guericke University Magdeburg, Germany

We study the mean-variance portfolio selection problem when both ambiguity attitude and model ambiguity of a decision maker are present. We consider an alpha-maxmin criterion that describes the mixture of ambiguity aversion and ambiguity seeking attitude of the decision maker. The uncertainty around the partial information about the underlying distribution of asset returns is captured by the Gelbrich ambiguity set, characterized by a reference mean and variance-covariance matrix. Extreme distributions (worst-case and best-case) in the ambiguity set associated with the minimal and maximal mean-variance portfolio values are obtained in closed form. The distributions provide valuable insights into the impact of the decision maker's ambiguity on the structure of extreme distributions. Depending on the risk aversion coefficient alpha, the optimal portfolio can be obtained via convex programming or difference of convex functions programming. Of particular interest are portfolios composed of heavy-tailed returns. In this case, we analyse existing methods to estimate the reference variance-covariance matrix from the data and discuss their influence on the optimal allocation. A numerical example illustrates the efficiency frontier of the portfolio and the sensitivity of the frontier to model uncertainty.

Impact of rough stochastic volatility models on long-term life insurance pricing

Jean-Loup Dupret, Université Catholique de Louvain, Belgium
Joint work with: Donatien Hainaut

The Rough Fractional Stochastic Volatility (RFSV) model of Gatheral et al. (Quant Financ 18(6):933–949, 2014) is remarkably consistent with financial time series of past volatility data as well as with the observed implied volatility surface. Two tractable implementations are derived from the RFSV with the rBergomi model of Bayer et al. (Quant Financ 16(6):887–904, 2016) and the rough Heston model of El Euch et al. (Risk 84–89, 2019). We now show practically how to expand these two rough volatility models at larger time scales, we analyze their implications for the pricing of long-term life insurance contracts and we explain why they provide a more accurate fair value of such long-term contacts. In particular, we highlight and study the long-term properties of these two rough volatility models and compare them with standard stochastic volatility models such as the Heston and Bates models. For the rough Heston, we manage to build a highly consistent calibration and pricing methodology based on a stable regime for the volatility at large maturity. This ensures a reasonable behavior of the model in the long run. Concerning the rBergomi, we show that this model does not exhibit a realistic long-term volatility with extremely large swings at large time scales. We also show that this rBergomi is not fast enough for calibration purposes, unlike the rough Heston which is highly tractable. Compared to standard stochastic volatility models, the rough Heston hence provides efficiently a more accurate fair value of long-term life insurance contracts embedding path-dependent options while being highly consistent with historical and risk-neutral data.

Optimal securitization of SME loans: the selection problem

Arnaud Germain, UCLouvain, Belgium
Joint work with: F. Vrins

Securitization is a powerful tool for central banks to stimulate the local economy: by purchasing SME loans bought from commercial banks, central banks can form credit pools, keep the first loss piece, and sell the senior tranche to investors. The junior tranche acts as a guarantee for the holders of the senior tranche, leading to a lower risk premium. This decreases the cost of money for corporates and, consequently, boosts the economic activity. This securitization process triggers a complex decision problem, which is the identification of the optimal set of loans out of N to be securitized for the sake of maximizing a given objective function, f. The optimization space is the set of N-dimensional vectors ω whose entries are binary decision weights ($\omega_i = 1$ if loan i is selected, $\omega_i = 0$ otherwise), where N is very large in practice. The objective function can take different forms but is typically non-linear in the decision weights. In addition, the decision problem is subject to budget and diversification constraints. All this together leads to a non-linear high-dimensional constrained integer (NP-hard) optimization problem. Of course, it is always possible to rely on derivative-free algorithms, but the convergence to a satisfactory local optimum is often disappointing.

In this paper, we consider the viewpoint of an investment fund leaning against a central bank willing to maximize the capital release resulting from the securitization process. In this case, the objective function f features the ratio of the Expected Loss (EL) over the Weighted-Average Life (WAL) of the pool. In order to tackle this problem in a reasonable amount of time, we revisit the initial optimization program in order to (i) relax the binary constraint, (ii) reduce the dimensionality of the problem and (iii) address the non-linearity of the objective function. First, we tackle the dimensionality and binary issues via clustering: the loans are aggregated in clusters, such that the selection problem collapses to determining the vector of optimal exposure to each cluster. The vector of binary weights will be determined in a second step, by selecting sequentially the loans that are closest to the centroids. Second, we linearize the EL of the senior tranche

(which is a non-linear function of the loss on the pool, hence, of the decision weights) thanks to the Large Homogeneous Portfolio approximation combined with a quadrature technique and Glover linearization scheme. We propose an analytical expression for the WAL accounting for prepayment using a continuous-time expression of the PSA prepayment model, which is standard in the mortgage-backed security industry. Our algorithm is proven to be very competitive compared to several benchmarks, such as derivative-free algorithms (Nelder-Mead), random selection or the best out of a set of portfolios built from heuristics, both in terms of the objective function and computation time.

Deep Hawkes Process for High-Frequency Market Making

Pankaj Kumar, Jheronimus Academy of Data Science, Netherlands

High-frequency market making is a liquidity-providing trading strategy that simultaneously generates many bids and asks for a security at ultra-low latency while maintaining a relatively neutral position. The strategy makes a profit from the bid-ask spread for every buy and sell transaction, against the risk of adverse selection, uncertain execution and inventory risk. We design realistic simulations of limit order markets and develop a high-frequency market making strategy in which agents process order book information to post the optimal price, order type and execution time. By introducing the Deep Hawkes process to the high-frequency market making strategy, we allow a feedback loop to be created between order arrival and the state of the limit order book, together with self- and cross-excitation effects. Our high-frequency market making strategy accounts for the cancellation of orders that influence order queue position, profitability, bid-ask spread and the value of the order. The experimental results show that our trading agent outperforms the baseline strategy, which uses a probability density estimate of the fundamental price. We investigate the effect of cancellations on market quality and the agent's profitability. We validate how closely the simulation framework approximates reality by reproducing stylised facts from the empirical analysis of the simulated order book data.

Bayesian Modelling and Statistical Machine Learning for Morbidity Rate Prediction

Kaitlyn Louth, The University of Edinburgh and Heriot-Watt University, United Kingdom
Joint work with: Prof George Streftaris and Prof Ruth King

Earlier work [1-3] has shown that population morbidity rates are idiosyncratic to a number of demographic and socioeconomic factors. More recent work [4,5, 6] has investigated morbidity risk for cancer, where it has also suggested differences in related time trends between the general population and an insured population in the UK, and respiratory admission rates in a US insured population. This project builds on this work to identify trends and important morbidity risk factors for cancer and a wider range of illnesses, also relating to healthcare provision and insurance. The principal aim of this research is to develop, evaluate and assess models for morbidity risk and related healthcare rates, under statistical approaches such as GLM-type and hierarchical Bayes models, that allow for uncertainty quantification. Aiming at improved predictions, traditional methods are combined with artificial neural network (ANN) deep learning techniques, by adopting a hybrid approach that embeds regression models in ANN settings. The work addresses the timely and pressing need to develop robust predictive models for rapidly changing morbidity risks and relevant impact on healthcare. Data from various sources are used, including the Office for National Statistics (ONS), NHS Open Data platform and insured population data provided by the Institute and Faculty of Actuaries (IFoA). The project includes the investigation of changes in morbidity rates for different diseases over time, and regional or socioeconomic differences. Further methodological work will be carried out towards assessing the robustness of the developed predictive models under a set of criteria designed to optimise the interpretability, predictive quality and uncertainty quantification. The research will provide robust models for morbidity rates, characterised for specific illnesses (e.g. cancer) and factors such as age, gender, and socio-economic status.

Efficient Collective Investment with Limited Expected Loss: Pareto-optimal Wealth Sharing and Risk Allocation

Tak Wa Ng, École d'Actuariat, Université Laval, Canada
Joint work with: Thai Nguyen

This paper investigates a collective investment problem under a limited expected loss (LEL) constraint in a complete market setting. We propose a novel LEL sharing rule as an alternative to widely used proportional sharing rules, demonstrating a direct correspondence between LEL sharing rules and constrained Pareto-optimal sharing rules. Under the financial fairness condition, we derive a unique LEL sharing rule through a straightforward fixed-point iteration. This rule connects each participant's share to the optimal terminal wealth in individual LEL-constrained scenarios, implying an intriguing recomposition effect. By evaluating the participants' tail risks via expected relative loss risk metrics, we formulate a novel Pareto-optimal risk allocation for such constrained collective risk management. Our numerical analysis affirms the theoretical findings and underscores the positive influence of the LEL constraint among prevalent proportional sharing rules, emphasizing the importance of risk control in practical scenarios. We observe that in contrast to LEL sharing rules, proportional sharing rules considerably lower reward-to-risk ratios for most collective members. This might discourage individual participation in the collective under an LEL constraint, conveying a cautionary message to collective planners regarding the determination of sharing rules.

State space decomposition and classification of term structure shapes in the two-factor Vasicek model

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Joint work with: Martin Keller-Ressel

Using the concept of envelopes we show how to divide the state space $\mathbb{R}^2$ of the two-factor Vasicek model into regions of identical term-structure shape. We develop a formula for determining the shapes utilizing winding numbers and give a nearly complete classification of the parameter space regarding the occurring shapes.

Catastrophe Bond Pricing Under Renewal Process

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Joint work with: D. Domfeh, Arpita Chatterjee

This paper introduces an innovative approach to catastrophe (CAT) bond pricing, addressing the shortcomings of existing methods that don't fully encompass catastrophe data characteristics or analyze the influence of both loss and inter-arrival time distributions on the CAT bond price. Our method combines the compound renewal process with the Cox-Ingersoll-Ross (CIR) process as a product measure to separately model uncertainties in insurance and financial risks. Valuation is performed in two steps, integrating risk-neutral measures for financial risks and a class of measures for insurance risks, preserving the structure of a renewal compound process. By using Bayesian inference, historical data, and capital market insights, we calibrate the pricing model effectively. Uniquely, our framework evaluates the impact of varying inter-arrival time distributions on CAT bond prices, an area previously unexplored in literature. This approach also separates market prices for claim frequency and severity under certain renewal process conditions. Empirical results reveal that inter-arrival time distribution notably influences the CAT bond price.

Equilibrium returns in markets with price impact and frictions

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Joint work with: Michail Anthropelos

We consider an Itô financial market where the assets' returns are derived endogenously through a market clearing condition amongst strategically behaved, risk-averse investors with quadratic preferences and random endowments. Agents act strategically by taking into account the impact that their orders have on the market's drift. Two cases are examined: one for a frictionless market and another for a market with frictions that are modeled via quadratic transaction costs. In the former we derive the unique Nash equilibrium at which investors' demand schedules reveal different hedging needs than the true ones implying, in turn, that the Nash equilibrium in this context deviates from the corresponding competitive one. For the case of frictions we note that while the frictional Nash equilibrium differs from its frictionless competitive and non-competitive counterparts, it is connected to both of them under special conditions.

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