Abstract booklet

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Keynote presenters

Christian Furrer
AP Pension & University of Copenhagen, Department of Mathematical Sciences

Session: Keynote 1
Time: June 15, 9.15 – 10.00

Title: Multi-state modeling in the mathematics of life insurance
Abstract:
It is not unusual for an insurance contract to concern multiple events, whether due to policyholder options (such as lapse, free policy conversion, and stochastic retirement), biometric conditions – as in disability and health insurance – or simply the fact that the policy is taken out on several lives. It therefore comes as no surprise that actuarial tables and formulas were used even a century ago to calculate reserves for specific contracts with multiple events. The distinctive Scandinavian influence began with Jan M. Hoem, who in the late sixties was arguably the first to establish a unifying actuarial framework based on Markov chains. In this framework, reserves are understood as conditional expectations, and earlier formulas emerge as corollaries to backward and forward equations for Markov chains. The introduction of an underlying stochastic model, the multi-state model, also paved the way for added risk assessments and the use of mathematical statistics in the compilation of actuarial tables. Both Hoem's professorship in Copenhagen and his research into multi-state models were continued by Ragnar Norberg, whose article "Reserves in life and pension insurance" published 1991 in the Scandinavian Actuarial Journal has proven formative for a generation of Danish actuaries. In this talk, I champion and challenge the classic Markov chain approach based on recent developments aimed at non-Markovian dynamics. Two subjects are given special attention. One is the calculation of expected cash flows and prospective reserves based on classic Markov chain formulas – but without assuming that the state process is Markovian; the central concept being the so-called forward (or conditional) transition rates. The other concerns safe-side calculations and other types of model comparison based on a stochastic version of Thiele's differential equation suitable for any actuarial multi-state model. By the end of the talk, we should have sampled some old wine in old bottles, some old wine in new bottles, some new wine in old bottles, and perhaps even some new wine in new bottles.

Karin Modig
Karolinska Institute, Unit of Epidemiology

Session: Keynote 2
Time: June 15, 16.15 – 17.00

Title: Living Longer, Aging Differently: Implications for Mortality Forecasting and Healthy Life Years

Abstract:
Over the past century, life expectancy has increased dramatically across much of the world. Early gains were driven by reductions in infant mortality and infectious diseases, while more recent improvements reflect advances in the prevention and treatment of chronic conditions. In high-income countries today, the vast majority of individuals reach old age, and survival patterns have become more predictable than ever before.

However, longer lives have also fundamentally changed the nature of aging. Survival has improved across most major diseases, with particularly large gains seen in conditions such as myocardial infarction, stroke, and several cancers. Diseases that were once rapidly fatal are now often managed over many years. As a result, aging today unfolds under very different biological and clinical conditions than in previous generations.

This shift raises important questions for both individuals and society. What does it mean to grow old in an era where disease is increasingly managed rather than cured? How should we understand trends in longevity when survival improves across multiple conditions simultaneously? And to what extent do these changes reflect a slowing of biological aging, as opposed to improved disease management?

By placing recent developments in a long-term perspective, this lecture will discuss how modern medicine has reshaped survival, health, and aging, and what this implies for forecasting mortality and managing longevity risk in an era of continued medical progress.

Mårten Palme
Stockholm University, Department of Economics

Session: Keynote 3
Time: June 16, 9.00 – 9.45

Title: The Rising Income Gradient in Life Expectancy in Sweden over Six Decades

Abstract:
We show that the income gradient in life expectancy in Sweden has steadily increased from 1962 to 2021, despite a reduction in income inequality until 1990. This challenges the "absolute income hypothesis" – the notion that economic resources per se affects life expectancy and that rising income inequality directly drives health disparities. Instead, a "third factor" appears to influence both income and life expectancy, leading to greater life expectancy gains among higher income groups. These gains are evident in both preventable and treatable disease mortality, suggesting that higher income individuals are more rapidly adopting healthier lifestyles and benefiting from medical advancements. This finding highlights the need to consider factors beyond economic resources in addressing health inequalities.

List of presenters (surname)

Cost-of-capital valuation with risky assets

Hansjörg Albrecher[1]

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Abstract

Cost-of-capital valuation is a well-established approach to the valuation of liabilities and is one of the cornerstones of current regulatory frameworks for the insurance industry. Standard cost-of-capital considerations typically rely on the assumption that the required buffer capital is held in risk-less one-year bonds. The aim of this work is to analyze the effects of allowing investments of the buffer capital in risky assets, e.g. in a combination of stocks and bonds. In particular , we make precise how the decomposition of the buffer capital into contributions from policyholders and investors varies as the degree of riskiness of the investment increases, and highlight the role of limited liability in the case of heavy-tailed insurance risks. We present a combination of general theoretical results, explicit results for certain stochastic models and numerical results that emphasize the key findings.

This is joint work with Filip Lindskog and Hervé Zumbach.

Incentive Pareto-Efficiency in Monopoly Insurance Markets with Adverse Selection

Maria Andraos[1]

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Abstract

We study a monopolistic insurance market with hidden information, where the agent's type θ is private information that is unobservable to the insurer. The hidden type affects both the loss distribution and the risk attitude of the agent. Within this framework, we show that a menu of contracts is incentive efficient if and only if it maximizes social welfare, subject to incentive compatibility and individual rationality constraints. This equivalence holds for general concave utility functionals. In the special case of Yaari Dual Utility, we provide a semi-explicit characterization of optimal incentive-efficient menus of contracts. We do this under two different settings: (i) the first assumes that types are ordered in a way such that larger values of θ correspond to more risk-averse types who face stochastically larger losses; whereas (ii) the second assumes that larger values of θ correspond to less risk-averse types who face stochastically smaller losses. In both settings, the structure of optimal incentive efficient menus of contracts depends on the level of the social welfare weight. Moreover, we show that in the first case, optimal retention functions are submodular, which ensures that higher types of the agent receive greater insurance coverage. In contrast, in the second case, optimal retention functions are supermodular, hence ensuring that lower types receive more coverage while higher types retain a larger portion of the loss.

Based on joint work with Mario Ghossoub.

The implied longevity surface: Deep calibration of stochastic mortality models

Aleksandar Arandjelović[1]

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Abstract

Actuarially fair pricing assumes the absence of insurer expenses and risk-based loads, whereas market prices of life-contingent insurance products incorporate factors such as operating costs, model risk and, more recently, climate risk. In quantitative finance, implied volatility represents the market-implied measure of expected uncertainty, inferred from option prices to calibrate models and assess risk. Building on this concept, [1] calibrated the deterministic, continuous-time Gompertz–Makeham law of mortality to life annuity prices using closed-form solutions, thereby extracting implied survival probabilities and implied life expectancies. However, the reliance on closed-form solutions imposes computational restrictions that hinder extensions to stochastic mortality models. Motivated by recent advances in the calibration of stochastic volatility models ([2]), we address these limitations using deep learning to generalize implied parameter calibration from deterministic, continuous-time to stochastic mortality models with flexible and potentially discrete payment structures. We present a versatile computational framework that uses deep neural networks to calibrate stochastic mortality models directly to market prices of life-contingent insurance products. Using data from major U.S. insurers offering life annuities, we calibrate an affine mortality model to annuity quotes across different ages and guarantee periods. The resulting difference between implied and realized longevity - the longevity spread - offers novel insights into the dynamics of life-contingent insurance markets.

This talk is based on joint work with Gaurav Khemka (Australian National University) and Pavel V. Shevchenko (Macquarie University).

References

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Insuring the lemons: The combined effect of collective experience rating and adverse selection

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[1]Aarhus University, Department of Economics and Business Economics, Denmark

Abstract

This article shows that an insurer can only obtain a fraction of the insurance market, when the premium is updated to reflect the current risk in its portfolio consisting of individuals with unknown reservation prices. This result aligns with general adverse selection theory, with an amplified effect from the collective experience rating. Further, this paper shows convergence of a model that combines collective experience rating and adverse selection, as well as finds an upper bound for the amount of individuals obtained by the insurance company in the long run. Using this bound, a starting point for the risk estimator is suggested, in the case of large markets.

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

Roberto Baviera[1]

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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.

References

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Impact of hedging on the cost of capital rate for hybrid life insurance

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Abstract

In the Solvency II framework for insurance, the cost of capital rate is a critical metric that encapsulates the cost of holding capital to meet regulatory solvency requirements, while also reflecting the investor's opportunity cost of capital allocation. Albrecher et al. [1] investigated the magnitude of this rate in the economic triangle of the policyholder, the shareholder, and the regulator. This paper seeks to extend that analysis by incorporating access to the financial market and focusing on hybrid life liabilities, which combine financial and mortality risks, thereby affording an asset-liability management perspective that insurers can employ to optimize business run-off. Furthermore, by incorporating partial hedging strategies, we show how hedging can affect both the numerator (i.e. the risk margin) and the denominator (i.e. the solvency capital requirement) of the cost of capital ratio. We focus precisely on when the hedging operation is considered effective. In particular, we demonstrate that, depending on its cost, effective hedging may not necessarily reduce the policyholder's risk margin. Our results provide insights into the practical limitations and regulatory implications of the cost of capital methodology in partially replicable environments.

Based on joint work with Karim Barigou and Pierre Devolder.

References

[1] Albrecher, H., Eisele, K.-T., Steffensen, M. & Wüthrich, M. V. (2022). On the cost-of-capital rate under incomplete market valuation. *Journal of Risk and Insurance*, 89(4), 1139–1158.

Optimal Equilibrium Investment and Insurance with State-Dependent Risk Aversion

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[2]University of Copenhagen, Department of Mathematical Sciences, Denmark

Abstract

We formalise a consumption-investment-insurance problem with state-dependent relative risk aversion, where the state is modelled by a finite-state Markov chain representing insurable risks such as health and lifetime uncertainty. We use certainty equivalents to quantify the economic value of uncertain preferences. This introduces time inconsistency, which we address using the equilibrium approach. We formulate and prove the verification theorem, deriving solutions for two different scenarios: logarithmic preferences and indifference to state changes. In both cases, it demonstrates how optimal strategies involve state-dependent adjustments in investment and insurance decisions.

Joint work with Mogens Steffensen.

A Seasonal Multi-Population Mortality Model with Climate Change Impacts

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Abstract

Climate change is reshaping seasonal mortality patterns as temperature extremes intensify, yet current annual stochastic mortality models fail to capture critical infra-annual dynamics for climate risk assessment. We develop a fine-grained daily multi-population mortality model that captures the link between seasonal mortality variations and temperature using a Distributed Lag Non-Linear Model (DLNM) [1, 2]. Our approach extends classical Age-Period-Cohort models [3] by incorporating a climate-modulated seasonality component that captures lagged, non-linear temperature effects with regional heterogeneity in long-term projections. Applying this framework to French departmental mortality data matched with high-resolution climate observations, we compare the predictive performance of model specifications based on annual death rates and mortality improvement rates [4]. Our approach enables projections under IPCC climate scenarios (RCP 4.5, RCP 8.5), supporting regulatory requirements for climate stress testing. Preliminary results show important improvement in forecasting accuracy during extreme temperature episodes and reveal significant regional variation in heat-mortality sensitivity, with material implications for life insurance reserving.

Based on joint work with Quentin Guibert.

References

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Couple tontines: Mutual joint-life and last-survivor insurance products

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Abstract

We develop a mutual tontine framework for couples, in which longevity risk is borne collectively by participants. We illustrate the framework with a joint-life tontine with survivor benefits, paying benefits during joint survival and continuing payments to the surviving spouse after the first death. The design builds on the modern tontine and pooled annuity fund literature, which studies arrangements in which risk is shared directly among participants rather than transferred to an insurer [1, 2]. While existing contributions focus primarily on single-life benefits, joint-life and survivor payouts have received only limited attention in pooled longevity settings, with notable exceptions such as [9].

By eliminating insurer risk absorption, the framework highlights the classical trade-off between higher expected lifetime income and increased payout variability.

The proposed scheme introduces explicit widowing credits and a joint-life state structure, extending fairness-preserving tontine designs for heterogeneous pools [3, 5, 4, 6]. The tontine is shown to be actuarially fair at all times, allowing heterogeneous couples to enter the pool at any date and mitigating small-pool effects as participation grows.

Both independent and dependent mortality are considered. Dependence between spouses' lifetimes is modeled using a parsimonious parametric framework calibrated to joint-life insurance data, linking the analysis to the literature on dependent mortality and joint-life annuity valuation [7, 8]. Numerical simulations illustrate the impact of mortality dependence on contribution levels, survivor benefits, and payout volatility.

(joint work with Peter Hieber)

References

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The Implications of Side Bequest Motives on the Life Insurance Decisions of Retired Couples

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Abstract

Recent empirical evidence shows that the death of a first spouse in retired couples leads to a sharp decline in wealth, reflecting not only reduced income but also additional transfers to heirs outside the couple. Such 'side' bequests have significant financial consequences for a surviving spouse, but the existing literature on financial decision-making does not account for them. To fill this gap, we build a model for optimal life insurance, consumption and portfolio decisions of a retired couple, with side bequest motives. Using analytical results and numerical simulations, we show that side bequests substantially alter couples' optimal life insurance and consumption decisions. In particular, we show that life insurance is an important tool that allows couples to balance their side bequest motive with the utility of a surviving spouse. Our model, therefore, highlights the importance of accounting for side bequests when making these decisions.

Quantifying epistemic uncertainty in gradient boosting via spectral decomposition of staged predictions

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Abstract

Gradient boosting for decision tree (GBDT) models are widespread in the insurance industry as they achieve state-of-the-art performance for tabular data. A limitation of GBDT models is the absence of a measure of predictive uncertainty, an element readily available in generalised linear models and essential in many high-stakes applications. Aleatoric uncertainty can be quantified with probabilistic predictions, mainly through probabilistic GBDT algorithms, as illustrated by [1]. Yet, the epistemic uncertainty component still needs investigation. In this work, we shift the perspective of existing propositions by leveraging the sequential nature of GBDT to construct a consistent model variance estimator and valid prediction intervals. We exploit the spectral decomposition of a GBDT staged prediction discrete-time stochastic process. After proving the consistency properties of our estimator, we dive into numerical results through simulation and real data actuarial applications, comparing the performance of our epistemic uncertainty quantification method against model-agnostic benchmarks: ensembling and conformal prediction.

References

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Pricing a guaranteed annuity option under a stochastic correlation setting.

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Abstract

Variable annuities are appealing investments given their guarantee features and tax-deferred characteristics. These are long-term contracts in which at the inception, the policyholder pays either a single lump sum premium or a series of periodic premiums to the insurer. The premium is invested in a fund at the policyholder's choosing. During the accumulation phase, the fund is managed by the insurer or a third party. At the contract's maturity that usually coincides with the policyholder's age of retirement, the policyholder has the option to: (i) either withdraw the entire fund at its current market value, (ii) or convert the accumulated fund value into a life annuity at a certain guarantee rate. This paper will deal with the technicalities of pricing a guaranteed annuity option (GAO) under a new framework that highlights the impact of correlation risk. Correlation plays a crucial role in financial pricing especially for contracts whose underlying variables are prices in a basket of dependent assets. Empirical evidence indicates that economic, financial and even demographic variables are correlated not only in a nonlinear fashion but also in a non-deterministic manner. The risk due to adopting a model that assumes an incorrect constant correlation could not be disregarded. It is far from reality that a constant correlation could be maintained for a long period of time. A constant correlation is certainly not a reliable measure of dependence. Ignoring a wrong correlation is referred to as correlation risk. Even though stochastic correlation was adopted in finance, it is clear that progress in correlation modelling has not caught up yet in actuarial science. This paper aims to address the lack of research attention in insurance valuation under a stochastic-correlation environment. Our contributions are three-fold. (i) We put together an integrated model setting wherein a correlation has proper temporal dynamics and it naturally fits with the interest rate and mortality risks' stochastic specifications. Additionally, such dynamics produce the correlation's stylised facts of taking values in (-1, 1), evolving around a mean value, and having a probability mass that tends to zero at the boundaries. (ii) To obtain, the almost explicit closed-form pricing solution, we customise the change-of-measure technique in order to bypass the formidably laborious "simulation-within-simulation" issue in GAO liabilities' numerical pricing. Through our numerical results, we establish that the computational capability of our proposed method manifestly surpasses that of the classical Monte-Carlo (MC) method. (iii) Our efficiently implementable

GAO valuation expression yield prices that are not different from those of the MC method serving as a benchmark, yet the computing speed of our approach is exceedingly superior to that of the MC method. This shows the reliability of our proposed approach when it comes to accuracy and computational efficiency.

Age-Gender-Country-Specific Death Rates Modelling and Forecasting: A Linear Mixed-Effects Model

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Abstract

A linear mixed-effects (LME) model is proposed for modelling and forecasting multi-population age-specific death rates [1]. The innovativeapproach that we take in this study treats age, the interaction between gender and age, their interactions with predictors, and cohort as fixed effects. Furthermore, we incorporate additional random effects to account for variations in the intercept, predictor coefficients, and cohort effects among different age groups of females and males across various countries. We will show that the LME model is identifiable. We will use data fromthe Human Mortality Database (HMD) to illustrate the procedure. We will assess the predictive performance of the LME model in comparison to theLee-Carter (LC) models fitted to individual populations. Additionally, weevaluate the predictive accuracy of the LME model relative to the Li-Lee(LL) model. Our results indicate that the LME model provides a more precise representation of observed mortality rates within the HMD, demonstrates robustness in calibration rate selection, and exhibits superior performance when contrasted with the LC and LL models.

References

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Single-population mortality models based on Linear Hypercubes

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Abstract

Exploiting the parallelism between mortality and credit-risk, we propose a mortality modeling approach based on the Linear Hypercube Model of [1], originally developed for credit-derivatives. This approach is particular attractive due to its analytical tractability while keeping always nonnegative mortality intensities. This approach can be used on a variety of applications, such as the explicit computation of standard actuarial quantities, the pricing of guaranteed annuity options and the estimation of multi-population mortality surfaces. Estimation can be performed using quasi-maximum likelihood in conjunction with the well-known Kalman Filter. We conduct extensive experiments to evaluate the adequacy of the proposed approach on the fitting of mortality surfaces.

This is a joint work with Marco Pirra (University of Calabria, Italy) and Fabio Viviano (University of Calabria, Italy).

References

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Measuring Financial Resilience Using Backward Stochastic Differential Equations

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Abstract

We introduce the *resilience rate* as a measure of financial resilience. It captures the expected rate at which a dynamic risk measure recovers, i.e., bounces back, when the risk-acceptance set is breached. We develop the corresponding stochastic calculus by establishing representation theorems for expected time-derivatives of solutions to backward stochastic differential equations (BSDEs) with jumps, evaluated at stopping times. These results reveal that the resilience rate can be represented as a suitable expectation of the generator of a BSDE. We analyze the main properties of the resilience rate and the formal connection of these properties to the BSDE generator. We also introduce resilience-acceptance sets and study their properties in relation to both the resilience rate and the dynamic risk measure. We illustrate our results in several canonical financial examples and highlight their implications via the notion of resilience neutrality.

This work is based on the paper [1], co-authored with Roger Laeven, Emanuela Rosazza Gianin, and Marco Zullino.

References

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When defaults cannot be hedged: an actuarial approach to XVA calculations via Local Risk-Minimization

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Abstract

In this paper we study pricing and hedging of counterparty credit risk and funding in absence of hedging possibilities against the default of the bank or the counterparty. We tackle the market incompleteness due to the presence of possible defaults with the well-known local risk-minimization approach extended to a multi-curve setting. We describe the optimal strategy via the solution of a BSDE and use this result to derive a decomposition of the price in terms of value adjustments. The 2007-2009 financial crisis provided the motivation for a critical review of several assumptions regarding the valuation of financial products. According to the market practice and the academic literature the value of a product should account for the possibility of default of any agent involved in the transaction. The presence of multiple interest rate curves for funding also represent a significant shift with respect to a classical single-curve asset pricing theory. Such aspects are captured by value adjustments (xVA), which are added or subtracted to an idealized reference price, in order to account for the aforementioned frictions.

By funding costs/multiple curves we mean that nowadays it is recognized, in line with realistic market conditions, that the trader can fund her trading activity by means of a multitude of sources of funding involving different interest rates. Funding and counterparty risk have been simultaneously considered afterwards, giving rise to the so-called xVAs, where the x represents a placeholder for different valuation adjustments.

In practice it is usually not possible to hedge against the default of the bank or the counterparty. However, the vast majority of the literature assumes a complete market setting. This is particulary evident in the initial contributions of Burgard and Kjaer, focusing on extensions of the classical Black-Scholes-type replication argument. In concrete terms, computing e.g. CVA under market completeness is based on the assumption that there exists some traded asset such as a corporate Bond or a CDS, such that the trading desk can hedge the jump to default of the counterparty. This assumption is justified only for a very limited set of bigger corporates. For most counterparties instead there exist no hedging instrument against the jump to default.

Regarding the hedging of the bank's default this is also problematic from a practical point of view: in concrete cases banks have been proxy-hedging their DVA by trading the CDS of peers i.e. of other investment banks. Such a practice can lead to an approximate hedge before default

but does not offer protection against the jump to default. For a bank, buying protection on her own default could even be prohibited under certain jurisdictions. Looking again at the existing literature, the aforementioned discounting approach of Brigo does not require market completenss: only the martingale property of certain cumulative discounted cashflows is postulated. A similar route that does not postulate replication has been followed by Crépey and coauthors from 2017 onward.

To summarize, default risk is in general difficult to hedge in concrete settings, up to the point where counterparty credit risk is essentially similar to an actuarial risk that is warehoused by the bank, in a fashion similar to an insurance company: the CVA is charged as an insurance policy premium to the counterparty and the default events erode a reserve. In this paper we study xVA valuation taking in account for market incompleteness by means of the local risk minimization approach.

This is a joint work with F. Biagini and K. Oberpriller (LMU Munich). The full paper is available for download at: https://arxiv.org/abs/2502.12774

Efficiently computing annuity conversion factors via feed-forward neural networks

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Abstract

Many pension plans and private retirement products contain annuity factors, converting the funds at some future time into lifelong income. In general model settings like for example the Li-Lee mortality model, analytical values for the annuity factors are not available and one has to rely on numerical techniques. Their computation typically requires nested simulations as they depend on the interest rate level and the mortality tables at the time of retirement. We exploit the flexibility and efficiency of feed-forward neural networks to value the annuity factors at the time of retirement. In a numerical study, we compare our deep learning approach to (least-squares) Monte-Carlo (LSMC) which can be represented as a special case of the neural network (NN). The presentation is based on [1].

References

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Aeda: A Practical Pipeline for Privacy-Preserving Insurance Data Pooling

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[1]Aeda, Oslo, Norway

Abstract

Small and mid-sized insurers struggle to compete on pricing accuracy due to limited data volume. Aggregating data across companies solves this but creates significant privacy challenges. In this presentation, we introduce Aeda, an operational platform for compliant insurance data pooling in the Norwegian market.

Moving beyond theoretical models, we demonstrate a production-pipeline that utilizes geographic aggregation, K-anonymity enforcement, and a re-distribution algorithm. This approach allows insurers to benchmark portfolios and improve pricing models without exposing sensitive customer data. We will discuss the practical trade-offs between GDPR compliance [2] and actuarial utility, showing how granular risk differentiation is achieved on fully anonymized datasets.

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An economic-environmental approach for regional mortality

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Abstract

Accurate modeling of regional mortality is a key issue in actuarial science, particularly for applications in life insurance, pensions. While the Lee-Carter [2] model and its extensions are widely used at the national level, their application to subnational populations is challenged by data volatility, overfitting, and limited interpretability. Moreover, standard mortality models rely almost exclusively on endogenous trends and do not explicitly account for economic or environmental heterogeneity across regions. This paper [1] addresses these limitations by proposing a parsimonious and interpretable multi-population mortality model that incorporates observed economic and environmental determinants.

We introduce an Economic-Environmental Lee–Carter (Eco-Env LC) model, which extends the classical Lee–Carter framework by combining a common endogenous mortality trend with multiple exogenous risk factors observed at the regional level. Mortality is modeled for European NUTS2 regions using a Poisson regression framework. In addition to a baseline age effect, the model includes a single common period factor with region-specific sensitivities to capture residual heterogeneity, as well as eight external economic and environmental covariates related to income, purchasing power, education, employment, healthcare resources, air pollution (NO2), and climate conditions (heating and cooling degree days).

A methodological contribution is the parametric specification of all age-dependent effects using B-splines. This approach ensures smooth mortality curves, limits the number of degrees of freedom, and avoids the overfitting problems commonly encountered in non-parametric multi-population models such as the Li-Lee [3] specification.

The model is estimated by maximum likelihood using mortality, economic, and environmental data from Eurostat and EDGAR for France, Italy, and Belgium–Netherlands over the period 2000–2023. Empirical results show that the inclusion of economic and environmental factors leads to a substantial improvement in goodness of fit compared to both the standard Lee–Carter model and a parametric Lee–Carter model without exogenous variables. Despite using far fewer parameters than the Li–Lee model, the Eco-Env LC model achieves comparable accuracy and is clearly favored by information criteria. Analysis of marginal effects highlights meaningful and heterogeneous impacts across ages and countries.

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On the optimality of full pension withdrawal for early home purchase

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Abstract

This talk discusses whether early access to pension savings can enhance housing accessibility. Households' purchase are modelled as a system of first-passage times with price feedback from aggregate demand. The analysis shows that households seeking to buy as early as possible optimally withdraw the full amount allowed. This reduces the social planner's problem to setting the policy cap. The main result establishes that granting full access is Pareto-optimal, as it shortens purchase times and increases the probability of purchase. Under equal return conditions, full withdrawal also reduces purchase gaps across households in the cohort.

Censored Heteroscedastic Extremes

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Abstract

We extend statistical estimation of extreme-value, non-identically distributed observations to the setting of random right-censoring. When the tails of the underlying events are proportional, and likewise for the censoring mechanism, the proportionality function for the tails of the underlying events can be estimated non-parametrically through the Beran estimator. To this end, we extend the uniform weak representation of the Kaplan-Meier estimator on increasing sets up to a given order statistic to the Beran estimator. In particular we provide an array representation of the empirical process of the Nelson-Aalen estimator and derive asymptotic error bounds that depend on the largest included order statistic; these bounds are of independent interest. The representation implies uniform consistency of the estimator of the tail-proportionality function; notably, under mild conditions, this result holds for any max-domain of attraction. We showcase the finite-sample performance through simulations and present an application to real data.

Based on joint work with Jan Beirlant and Martin Bladt.

Deep learning methods for loss simulation in a multi-peril insurance portfolio

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Abstract

In a portfolio where each policyholder is exposed to losses under multiple perils, calculating value-at-risk requires an understanding of the dependency structure among perils. Traditional methods often require assuming a specific parametric copula family. In this work, we investigate deep learning architectures to learn these dependencies directly. First, we explore Conditional Variational Autoencoders (CVAEs) to model the joint density of losses directly. Second, we employ a two-step approach: fitting marginal models for each peril and using Normalizing Flows to estimate the dependency density of the residuals. By learning a sequence of invertible transformations, Normalizing Flows map simple base distributions to complex target densities without restrictive shape assumptions. We compare these methods using simulated data and demonstrate their capacity to capture tail dependencies, facilitate portfolio loss simulation, and accurately estimate Value-at-Risk.

This is joint work with Katrien Antonio (KU Leuven, Belgium & University of Amsterdam, The Netherlands) and Marie-Pier Côté (Université Laval, Canada).

Disability insurance with collective health claims: A mean-field approach

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Abstract

The classic semi-Markov disability model is expanded with individual and collective health claims to improve its explanatory and predictive power – in particular in the context of group experience rating. The inclusion of collective health claims leads to a computationally challenging many-body problem. By adopting a mean-field approach, this many-body problem can be approximated by a non-linear one-body problem, which in turn leads to a transparent pricing method for disability coverages based on a lower-dimensional system of non-linear forward integro-differential equations. In a practice-oriented simulation study, the mean-field approximation clearly stands its ground in comparison to naïve Monte Carlo methods. (This is joint work with Christian Furrer from the University of Copenhagen.)

Driving Behavior Bonus–Malus System: Enhanced Risk Classification Through Telematics and Neural Modeling

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Abstract

Traditional auto insurance pricing relies on demographic proxies that poorly reflect actual driving risk, creating systematic inequities where safe drivers subsidize dangerous ones. We develop a Driving Behavior Bonus-Malus System (DBBMS) that combines telematics-measured driving behavior with claims history to achieve fairer, more accurate risk pricing. Using unsupervised K-means clustering on telematics data, we identify three distinct driving profiles: conservative drivers (76.7%) characterized by gentle patterns, aggressive-cornering drivers (12.8%) distinguished by sharp turns, and harsh-braking/acceleration drivers (10.5%) marked by intensive brake and acceleration patterns. We develop a hurdle-Tweedie neural network framework combining Combined Actuarial Neural Networks (CANN) with gated feature selection to model claim occurrence and severity. The cluster variable emerges as the most informative feature, achieving near-perfect calibration (1.002) and lower prediction errors compared to traditional GLM approaches. In the DBBMS, we address two critical deficiencies in traditional systems: financial imbalance and non-monotonic pricing. By deriving optimal relativities under financial equilibrium constraints with linear restrictions, DBBMS produces moderate, monotonically increasing premium scales (0.8–1.2) with balanced portfolio distribution across all levels (26%, 17%, 16%, 14%, 28%), compared to traditional systems where 97% of policies concentrate in the lowest levels with extreme relativities exceeding 6.0 that are rarely applied.

This is joint work with Eric C.K. Cheung, Andres Villegas Ramirez and Jae-Kyung Woo.

Keywords: Usage-Based Insurance, Telematics, Bonus-Malus System, Machine Learning, Hurdle-Tweedie Model, K-means Clustering, Neural Networks, Risk Classification

A Multivariate Energy-based Fairness Adjuster for Premiums

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Abstract

Fairness in insurance pricing has received increasing attention, particularly in light of regulations calling for non-discriminatory premium estimation such as the EU Gender Directive (2012). This research focuses on removing structural bias in predicted premiums as a solidarity-driven fairness concept [1]. We propose a gradient-based distributional adjustment designed to mitigate disparities across protected groups. The method relies on the Energy distance [2], a multivariate metric that enables the joint alignment of predicted premium distributions across multiple sensitive attributes (including non-binary ones) simultaneously. To maintain overall prediction balance, a post-hoc autocalibration step corrects biases in the total predicted number of claims [3]. In addition, the method supports fairness adjustments for new policyholders without requiring retraining of the underlying prediction model. We evaluate the proposed methodology in a car insurance pricing setting, where demographic factors such as age and gender are commonly used for risk assessment and premium determination. Results show that the method effectively reduces group-level disparities while retaining a significant share of predictive accuracy.

This is joint work with Donatien Hainaut.

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Bagging and regression trees in individual claims reserving

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Abstract

This presentation introduces an advanced machine learning approach to individual claims reserving. Claims reserving seeks to stochastically predict future loss reserves needed to cover potential claims. Our paper [1], which in a way extends the work of Wüthrich [2], proposes a methodology that combines regression trees with bootstrap aggregating (bagging) to enhance prediction accuracy and model stability. Unlike traditional approaches that analyze claim frequency and severity separately, our model captures both aspects simultaneously. The use of out-of-bag error diagnostics strengthens model validation. A real-world data example demonstrates the method's capability to produce more precise reserve estimates, emphasizing its practical relevance for actuarial applications.

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Multivariate subexponentiality and interplay of insurance and financial risks in a renewal risk model

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Abstract

During last decade, although the study of continuous time risk models with heavy-tailed claims and presence of stochastic returns became quite popular, due to its practical applications, still it is lacking the emphasis in modeling the dependence among these two fundamental risks, that seems necessary for the modern insurance industry. In this paper we consider a multivariate risk model with common renewal process, while the logarithmic returns of the insurer's investment portfolio, are described by a Lévy process.

In the two main results are established an asymptotic expression for the entrance probability of the discounted aggregate claims in some 'rare' sets $x\,A$. This asymptotic expression highlights the multivariate linear single big jump principle in asymptotic behavior of these probabilities.

In the first result, we are restricted in the case where the insurer makes risk-free investments, and hence we consider a non-negative Lévy process. We assume that the claim vectors follow a distribution from the class $\mathcal{A}_A^*$, introduced here, and represents a negligibly smaller subclass of class $\mathcal{S}_A$ of multivariate subexponential distributions on A, since the additional requirement for positive lower Karamata index, looks as a quit mild condition. Further, we consider that the insurance and financial risks, satisfy a weak, but very general dependence structure.

In the second result, we allow arbitrarily dependence between the two risks, and we assume that the distribution of their product, at each renewal epoch, belongs to the class $(\mathcal{D}\cap\mathcal{A})_A \subsetneq \mathcal{S}_A$. In this theorem we also permit risky-investment, putting a condition to Laplace exponent of the Lévy process, related with the upper Matuszewska index of the distribution for the product insurance and financial risks. We also note that even in the special one-dimensional sub-case the main results are new.

Furthermore, we present two examples, where we demand only conditions for the marginal distributions of both risks and their dependence structure. In the first example, we consider the weak dependence structure, used in the first theorem, and the insurance risks dominate against the financial risks. In the second example we take a strong dependence structure, and we also allow the cases where the financial risks dominate against the insurance risks, or the two risks have equal "heaviness". Both examples, under the restriction on multivariate regularly varying distributions provide more explicit and elegant relations in relation with that

established in the main results. Finally, we give an application of the results for the asymptotic estimation of the infinite-time ruin probability.

This is joint work with Charalampos D. Passalidis.

Boosted Varying Coefficients for Interpretable Multi-State Recurrent Event Modelling

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Abstract

We introduce varying coefficients for modelling hazard rates within a multi-state recurrent event point process framework. Information regarding previous events and the current state are captured in the (time-varying) covariates in order to predict future events. Expanding on the classical Cox model, we replace the constant coefficients in the relative risk function with *varying coefficients* that are functions of the full covariates as well as time. This allows the model to better capture temporal trends, non-linear effects, and interactions not possible in the Cox model, while retaining interpretability. The coefficient functions are estimated using tree-based gradient boosting. We compare the proposed approach with the Cox model, as well as a single gradient boosted machine (GBM) on the relative risk function, which is more flexible at the cost of next to no explainability. Evaluating on simulated data, we find that the varying coefficient model's performance is similar to that of the single GBM, while allowing for more interpretable output.

The presentation is based on ongoing work together with Mathias Lindholm and Filip Lindskog.

Assessing Driving Risk using Telematics Data: a Wavelet Transform Approach

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Abstract

Vehicle telematics provides granular data for dynamic driving risk assessment, but most existing methods to assess driving risk rely on aggregated metrics/summary statistics. As a result, they do not fully exploit the rich time-series structure of trip data. In this project, we propose the use of wavelet transform to capture key driving patterns of trips which in turn are used to evaluate driver and trip-level behaviors. By incorporating measures of both frequency and severity of acceleration events, this approach enables to distinguish aggressive and inattentive driving from normal driving behavior, as demonstrated in a control study. Furthermore, the approach enhances interpretability, reduces misclassification, and provides a flexible foundation for fully telematics-based risk assessment.

This is joint work with Andrei Badescu and Jongtaek Lee.

Multi-state health modelling using machine learning techniques

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Abstract

The presentation discusses different approaches to multi-state health modelling using machine learning techniques, when the underlying data generating process is described by a marked point process. Particular focus will be on multi-type point processes with recurrent events, and how individual life histories can be learned and approximated. An example using ideas from large language models (LLMs) will be illustrated based on synthetic data.

The presentation is based on ongoing work together with Filip Lindskog and Leo Levenius.

Hazard estimation with time-dependent covariates using landmarking supermodels and boosted trees

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Abstract

In the era of modern information systems, high-dimensional and time-dependent covariates are becoming increasingly prevalent. Dynamically predicting future events (e.g. insurance claims) in this setting poses significant statistical challenges. Traditional approaches like joint modeling are often computationally intensive and rely on restrictive parametric assumptions, while standard landmarking methods can suffer from information loss or temporal inconsistencies [1, 2, 3]. A recent contribution uses tailored kernel estimators to address these theoretical hurdles [5], but the approach relies on strong homogeneity assumptions and scales poorly to high dimensions. We propose a novel approach for estimating hazards with time-dependent covariates using landmarking supermodels [1] combined with boosted trees. Our method effectively handles high-dimensional covariate processes and can be implemented via standard software such as XGBoost [4]. We establish weak consistency of the proposed estimator within a sieve estimation framework and show that the approach addresses the consistency condition violations that have plagued existing landmark models. Data applications demonstrate that the method produces accurate individualized dynamic prognoses.

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on time-homogeneous high-quality marker information. *Biometrika*, 112(2), asaf008.

On the main determinants of medical costs in accident insurance: a comprehensive analysis of the Swiss market

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Abstract

Professional accident insurance (or workers' compensation) covers medical expenses and salary replacement following accidents. Unlike other insurance branches, it operates under a single group policy per company, with premiums varying by company characteristics, region, industry sector, claim history, and other factors. In Switzerland, this insurance is mandatory and divided into two branches: work-related accidents and leisure-time injuries. Using a novel dataset covering the entire Swiss accident insurance market with over 1.5 million companies from 2003 to 2019, we investigate the determinants of medical costs arising from accident insurance claims. This dataset enables, likely for the first time, a direct comparison of work- and leisure-related accidents, the latter of which are rarely examined in the existing literature. Surprisingly, we detect several work-related variables (for example company size, industry sector) either directly or indirectly affecting medical costs for leisure-related accidents. We use regression models to identify and quantify differences across business activities, company sizes and geographical regions. This is joint work with Peter Hieber and Joël Wagner.

How does health prevention affect longevity and portfolio decisions?

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Abstract

This paper presents a novel framework that integrates preventive health expenditures into a lifetime portfolio selection model under un- certain lifetimes. By combining financial portfolio optimization with actuarial mortality modeling, we examine how health investments affect individual longevity and financial decisions. The age at death is treated as a random variable, and individuals allocate a fraction of their wealth to prevention to reduce mortality risk and extend life expectancy. This endogenous link between health spending and survival enables us to explore the dynamic interplay between wealth accumulation, longevity, and health behavior over the lifecycle. Our contribution is therefore to build a bridge between the financial, actuarial and medical domains. From a financial perspective, we extend Merton's canonical portfolio model to include health expenditures that influence the random lifetime horizon. Actuarial principles are used through the Gompertz mortality law, which we reparameterized to capture the potential reduction in mortality from preventive care. While stylized, this formulation paves the way for more intricate medical and demographic modeling of how health investments can shift mortality curves. Empirical simulations show that optimal prevention strategies vary systematically by gender, age, and country-specific mortality profiles, underscoring the role of personal and demographic factors in shaping the trade-offs between investment and health. These findings offer valuable insights for both individual financial planning and the design of public health policies in an era of increasing longevity and growing economic-health interdependence.

Utility-optimal balancing of positive and negative basis risk in parametric insurance with expectile payment schemes

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Abstract

Parametric insurance contracts translate index measurements to compensation for policyholders' losses using predefined payment schemes. These need to be designed carefully to keep basis risk, i.e. disparities between payouts and true damages, small. Previous research has motivated the use of conditional expectiles as payment schemes, whose compensation can be heavily impacted by the policyholder's potentially unknown attitude towards basis risk. To alleviate this model uncertainty and investigate the impact of (hidden) influence factors, we characterize existence and uniqueness of the optimal basis risk weighting in a utility-maximization framework through a set of boundary conditions and offer guidance for its numerical derivation. In the absence of an optimal solution, we provide comparisons to the utility of no insurance and full indemnity coverage. As part of our investigations, we establish a link between location-scale distributions and separability of conditional expectiles' derivatives, improving the understanding of these important statistical functionals. A simulation study on parametric hurricane insurance visualizes our results, investigates the influence of premium loading and risk aversion on the optimal weighting, and comments on the challenge of (spatial) loss dependence.

Joint work with Matthias Scherer.

Can we rely on Spearman's ρ for sparse financial time series? Evidence from Operational Risk in Insurance

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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. [1, 2].
We prove that when applied to financial time series with a significant number of zeros, Spearman's ρ can produce widely varying correlation estimates. In such cases, financially equivalent time series – i.e. time series that differ by a negligibly small amount – can record highly different Spearman's correlations.
We perform an experimental analysis using data from the *ORX Global Insurance* dataset, the world's largest operational risk loss dataset in the insurance sector [3]. We show that the presence of zeros induces systematic instability in Spearman's ρ, compromising its reliability for operational risk assessment. We further quantify the financial impact of this instability by translating it into Solvency II capital requirements [4], highlighting implications for actuarial risk management.

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On a risk model with tree-structured Poisson Markov random field frequency, with application to rainfall events

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Abstract

In many insurance contexts, dependence between risks of a portfolio may arise from their frequencies. We investigate a dependent risk model in which we assume the vector of count variables to be a tree-structured Markov random field with Poisson marginals. The tree structure translates into a wide variety of dependence schemes. We study the global risk of the portfolio and the risk allocation to all its constituents. We provide asymptotic results for portfolios defined on infinitely growing trees. To illustrate its flexibility and computational scalability to higher dimensions, we calibrate the risk model on real-world extreme rainfall data and perform a risk analysis.

Joint work with Hélène Cossette, Benjamin Côté and Alexandre Dubeau.

Optimal investment in DC pension schemes under career-driven wage uncertainty

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Abstract

In defined-contribution (DC) pension schemes, members must manage investment risk while ensuring they accumulate sufficient wealth for retirement. At the same time, labor income risk plays a crucial role, as it governs the contribution stream. We study the optimal investment problem of a DC pension fund member in the presence of unhedgeable wage risk driven by idiosyncratic career dynamics. Building on [1], labor income follows a regime-switching process governed by a continuous-time Markov chain; differently from their setting, here the switching states represent ordered career phases (e.g. bad, stagnant, and good) rather than aggregate economic conditions. Contributions are defined as a fixed fraction of such stochastic labor income, and financial investment takes place in a standard Black–Scholes market. The pension fund member maximizes expected utility of terminal wealth under CARA preferences. We solve the problem via dynamic programming and derive closed-form expressions for the value function and the optimal portfolio rule. Due to our use of CARA preferences, the optimal risky allocation is independent of both wealth and labor income. The key implication, however, concerns the impact of career dynamics on retirement outcomes: under a monotone transition structure, we establish stochastic ordering results [2] showing that better initial career phases lead to systematically higher terminal pension wealth. Yet this ranking reverses when performance is measured in relative terms via the replacement ratio: indeed, individuals starting in better career phases tend to achieve lower replacement ratios. This mechanism is consistent with the theoretical insights in [3] and with the empirical evidence documented in [4]. Overall, our results show that career dynamics shape not only wealth accumulation but also pension adequacy, generating persistent and economically meaningful heterogeneity in retirement outcomes even under identical optimal investment policies.

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Probabilistic Crop Yields Forecasts With Spatio-Temporal Conditional Copula Using Extreme Weather Covariates

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Abstract

We introduce a novel forecasting model for crop yields that explicitly accounts for spatio-temporal dependence and the influence of extreme weather and climatic events. Our approach combines Bayesian Structural Time Series for modeling marginal crop yields, ensuring a more robust quantification of uncertainty given the typically short historical records. To capture dynamic dependencies between regions, we develop a time-varying conditional copula model, where the copula parameter evolves over time as a function of its previous lag and extreme weather covariates. Unlike traditional approaches that treat climatic factors as fixed inputs, we incorporate dynamic Generalized Extreme Value models to characterize extreme weather events, enabling a more accurate reflection of their impact on crop yields. Furthermore, to ensure scalability for large-scale applications, we build on the existing Partitioning Around Medoids clustering algorithm and introduce a novel dissimilarity measure that integrates both spatial and copula-based dependence, enabling an effective reduction of the dimensionality in the dependence structure. [1].

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Optimal Additional Voluntary Contribution in Defined-Contribution Pension Schemes Under a Stochastic Wage Environment

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Abstract

Members of a Defined Contribution (DC) Pension Scheme face the risk of accumulating insufficient retirement savings due to unfavorable financial and labor market conditions. To reduce this risk, they may choose to make additional voluntary contributions (AVCs) beyond the amounts mandated by the pension plan. Most existing models, to the best of our knowledge, treat AVCs either as fixed or otherwise exogenously determined, with a few exceptions [1, 2] that consider them as stochastic control variables. In this paper, we also model AVCs as control variables within a continuous-time, target-based stochastic optimization framework, in which the member simultaneously selects the investment strategy and the level of AVCs throughout their working life. The model captures the trade-off between contribution stability and achieving the target annuity at retirement, consistent with other target-based pension optimization studies [3, 4]. We solve the problem in a stochastic environment with a complete Black–Scholes financial market and random wages, deriving closed-form solutions, performing numerical simulations, and conducting sensitivity analyses to evaluate the impact of different preferences and the robustness of the optimal strategies.

Joint work with Francesco Menoncin and Elena Vigna.

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Transformed gradient based boosting

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Abstract

We introduce a boosting method using transformed gradients(TGB) that includes gradient boosting machines, XGBoost, and NGBoost as special cases. Within this framework, we derive explicit sufficient conditions guaranteeing in-sample loss improvement and convergence. Specializing to regression trees yields an alternative proof of convergence and improvement results for GBMs and XGBoost.

Our analysis also shows that NGBoost is not guaranteed to converge unless weighted regression trees are used. Furthermore, we show that NGBoost using weighted regression trees can be seen as a version of XGBoost, where the Hessian, i.e. observed Fisher information matrices, are replaced by the corresponding expected Fisher information matrices.

Finally, in insurance applications the loss functions that are used are given by negative log-likelihoods of exponential dispersion family (EDF) models. The effect of using EDF models in combination with natural gradients and NGBoost is discussed in detail, including the order in which parameter dimensions are updated, and how exposure weights can be included in the boosting procedure in a natural manner.

Bayesian Classification of Binary Outcomes from Unbalanced Matrix-Valued Predictors with Unsupervised Clustering

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Abstract

Many actuarial datasets contain different numbers of repeated observations for each individual (e.g. a varying number of claims per policy) that exhibit latent, within-individual heterogeneity. As an example, consider occasional highly severe claims which have markedly different characteristics than more frequently occurring, low-severity claims. A naive approach would be to model such unbalanced claims data would be to simply average the feature values across all claim subtypes within an individual. However, such averaging may lose valuable information about the heterogeneity between latent subgroups. An alternative strategy recently proposed in [1] is the CLUstering Structured lasSO (CLUSSO) method which addresses this problem in the continuous-outcome setting by combining within-entity clustering with L^1-penalised regression on the resulting empirical means of the clustered subgroup feature vectors. In this work, we propose a Bayesian generalisation of CLUSSO for binary outcomes which we refer to as Gaussian Latent Averaging for scalar-on-Matrix regression (GLAM). Instead of committing to a single subgroup allocation for the computation of subgroup feature means, GLAM explicitly marginalises over the posterior predictive distribution of a Gaussian Mixture Model. GLAM is very flexible and allows a straight-forward generalisation to any GLM-problem including continuous, count and time-to-event outcomes. Further, using a Bayesian framework allows for more sophisticated sparsity-promotion compared to simple L^1-regularisation as well as the incorporation of domain-specific knowledge to guide the relative prevalences of different subgroups. We compare the performance of GLAM to naive averaging of entities across all subgroups per individual on the task of feature selection and predictive performance, and highlight the potential to apply the method to claims data in bonus-malus pricing of non-life insurance products. In [2] claims data is used to infer a latent unobservable policy "state" that evolves across time, which represents one form of claim to policy-inference. To our knowledge, however, no method similar to GLAM or CLUSSO has been applied in the actuarial context before, with most existing literature instead focusing on HMM approaches.

Joint work with Jeremy Rubin.

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Scoring Rules with normalized order statistics to determine tail-index

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Abstract

This presentation proposes a scoring-rule-based method for ranking predictive distributions in the Fréchet domain that can distinguish between different tail indices. The approach is built on normalized order statistics and uses proper scoring rules to compare tail limit distributions within a distributional framework. Simulation results show that the method is able to discriminate between different tail behaviors in finite samples and that random multiplicative scaling has only a minor effect on its stability. The practical relevance of the approach is further illustrated through an application to insurance claims data. We further show that minimizing scoring rules yields consistent tail index estimators and that the classical Hill estimator arises as a special case. The performance of the proposed method is studied and compared with that of the Hill estimator across a range of tail indices.

Variance allocation and p-values of categorical variables in generalized additive models

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Abstract

We study the problem of variable importance in Generalized Additive Models (GAMs). Analytical Shapley values for variance allocation in GAMs have been recently derived in [1], where the importance of a numerical variable is quantified through its covariance with the model output. However, these indices are not well defined for categorical variables.
In this work, we address this limitation by constructing Shapley values for variance allocation in the case of categorical variables. Our approach builds on the Shapley values of the associated one-hot encoded variables. We show that the sum of the Shapley values across all levels of a categorical variable yields the Shapley value for the entire variable, which remains invariant to the choice of reference category. We also derive confidence intervals for these values and prove their invariance.
Finally, we prove that the p-value associated with a categorical variable is also invariant to the reference category, while the Shapley values and p-values change after changing the reference level. Numerical simulations and applications illustrate our findings.
This presentation is based on a joint work with Lorenzo Calvetti (Columbia University) and Amir Khorrami Chokami (University of Cagliari).

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A Dynamic Common-Factor Model for Cyber Accumulation Using Public Breach Notifications

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Disclaimer: This work reflects the author's personal research and opinions and does not represent the views of HSB Canada or Munich Re.

Abstract

Cyber accumulation occurs when many insureds (or many parts of a portfolio) experience elevated incident activity at the same time. A static dependence assumption can miss this because the cyber environment does not sit still. The practical question is not whether incident counts drift, but whether that drift is shared across segments in a way that inflates tail risk.

We study this using publicly available breach notification records aggregated to a monthly panel of counts. Notifications are grouped into a small number of segments (for example, by incident category and organization type) to form parallel time series. We model these counts with a shared-factor intensity structure: conditional on a latent systemic factor, segment counts follow a Poisson or negative binomial model with an exposure offset and a segment sensitivity, so different segments can respond more or less strongly to the same systemic conditions. The systemic factor evolves over time through a persistent state equation, allowing systemic pressure to build and unwind.

Because the observations are counts, we estimate and update the systemic factor using likelihood-based nonlinear filtering (extended or unscented Kalman filtering) combined with standard calibration of model parameters. We evaluate one-step-ahead predictions against simple actuarial baselines such as a rolling-window mean and a static intensity model. To connect the fitted model to accumulation decisions, we propagate the time-varying intensities through an aggregate-loss layer and report how quantities used in practice—such as the probability of exhausting an annual aggregate limit and tail risk measures like Expected Shortfall—change when systemic pressure is elevated.

The output is a filtered systemic index with uncertainty bands and segment sensitivities that summarize accumulation risk. Since breach notifications are not insured losses, we present the model primarily as a monitoring and stress-testing tool that complements internal experience rather than as a direct substitute for loss data.

Collective pension design for homeowners and renters

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Abstract

We study the impact of a one-size-fits-all pension provider's asset allocation strategy on pension plan participants who are heterogeneous in their homeownership status. Using a quantitative life-cycle model of optimal consumption and savings decisions, we first derive the optimal collective strategy that takes both homeowners and renters into account. Second, we determine the utility losses from exposure to the collective asset allocation strategy versus an individually optimal one. Third, we examine how individuals can correct for the collective asset allocation strategy by altering their private consumption and savings decisions outside the pension environment. This talk will be based on joint work with Anne Balter, Marlene Koch, Paulo Rodrigues and Nikolaus Schweizer.

Insurance Risk Models with Epidemic Dynamics: Scaling Limits and Ruin Asymptotics

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Abstract

Recent pandemics and the growing interplay between epidemiological dynamics and insurance outcomes have motivated us to develop insurance risk models that explicitly link the claims process to the underlying infection status of the population. To keep things simple, we consider two subgroups representing people with or without a particular disease, or people with or without a healthy lifestyle. More generally, our modelling framework can be applied to a wide range of situations in which a portfolio of insurance policies can be divided into sub-populations with different risk characteristics.

By incorporating epidemic-type dynamics into an actuarial risk framework, we seek to understand the impact of contagion-driven transitions between health states on the aggregate claims process and, ultimately, the solvency of the portfolio. Our analysis focuses on two key aspects: scaling limits for the resulting risk processes, and deriving bounds and asymptotic approximations for the corresponding ruin probabilities.

This is joint work with Hélène Guérin (UQAM), Michel Mandjes (Leiden) and Arsene Zotsa (UQAM).

Socio-economic disparities in the limits of human lifespan: an extreme value theory approach

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Abstract

Accurate estimation of mortality at older ages is crucial for (re)insurance companies, pension funds, and healthcare providers, for example, to price life annuities and reverse mortgages, as well as for the valuation of pension liabilities. Closely related to this, an important topic in mortality and ageing research is the existence of a limit to the human lifespan. However, the limited number of deaths at the oldest-old combined with relatively low population exposures makes this question challenging to study. In addition, exact ages at death at the oldest-old are frequently missing or misreported, which adds further complexity to the problem. To account for these challenges, we use tools from extreme value theory to study the tail of the lifetime distribution and rely on a unique individual-level microdataset from Belgium and the Netherlands covering all individuals who died or were still alive above age 90 during the periods 1992–2022 (Belgium) and 1995–2022 (the Netherlands). These lifetime exceedances above a high pre-selected threshold age are assumed to follow a Generalised Pareto distribution, governed by a scale and a shape parameter. In our case study, we estimate a negative shape parameter, which provides evidence in support of a theoretical upper limit to the human lifespan. In addition, the microdata include rich demographic and socio-economic characteristics such as gender, origin, marital status, education, and household information. By allowing the scale parameter to depend on these covariates, the novelty of our study lies in assessing how maximum lifespans differ across socio-economic groups and in comparing these patterns between Belgium and the Netherlands. Given rising life expectancies and the post-war baby boom cohort now reaching ages 80 and above, this topic will grow increasingly important in the coming years.

Joint work with Torsten Kleinow.

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Enhancing Mortality Forecasting with Ensemble Learning

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Abstract

A well-established insight in forecasting is that combining predictions from multiple models often improves accuracy and robustness compared to selecting a single best model. This paper proposes a novel ensemble strategy that leverages Shapley values, a game-theoretic measure of each model's marginal contribution to predictive performance, to construct interpretable combination weights. We compute SHapley Additive exPlanations (SHAP)-based weights age-by-age, thereby capturing the specific contribution of each model at each age. In addition, we introduce a thresholding mechanism that downweights or excludes models with negligible marginal contributions, thereby reducing forecast variance and limiting overfitting. We illustrate the approach on a large panel of stratified time series from actuarial and demographic contexts, and we report consistent improvements in out-of-sample forecasting performance, especially at longer horizons. By exploiting complementary strengths across candidate models and filtering those that add limited predictive value, the proposed method provides a robust and transparent framework for improving forecasts in applications involving structured rates and risk-related quantities.

Joint work with Giovanna Bimonte, Han Lin Shang and Yang Yang.

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Actuarial applications of epidemic models

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Abstract

With the recent outbreak of COVID-19, assessing the risks associated with the spread of infectious diseases has become an important and increasingly significant task. The ability to understand, model and predict the dynamics of infectious disease transmission plays a key role in combating the pandemic. This paper provides an overview of basic models and analyses the Susceptible-Exposed-Infected-Containing-3-Substates-Recovered-Dead model for studying the dynamics of COVID-19. A meticulous data calibration procedure is used to study the evolution trend of the actual pandemic using real data from the Mazovian Voivodeship in Poland. In addition, the paper discusses the innovative application of epidemiological models in the insurance industry.

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A Hierarchical Bayesian Framework for Delay-Adjusted Cybersecurity Breach Modeling

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Abstract

Cybersecurity breaches are often disclosed with substantial reporting delays, generating systematic bias in real-time risk assessment, actuarial reserving, and financial decision-making. Building on advances in Bayesian nowcasting, this study develops a probabilistic framework to correct for delayed breach reporting and to estimate the true volume of Incurred But Not Reported (IBNR) cyber incidents. Focusing on representative U.S. states with comprehensive and frequently updated breach archives, the proposed Bayesian model explicitly adjusts for reporting delays and decomposes observed breach counts into interpretable temporal, seasonal, and delay-related components.

The methodology adapts techniques originally developed in epidemiology and insurance reserving to the context of cyber risk. By explicitly modeling overdispersion and multiple sources of uncertainty, the framework improves the robustness and interpretability of breach frequency estimates and associated reserve risk measures. Empirical validation using U.S. State Attorney General breach data demonstrates enhanced predictive accuracy for undisclosed incidents and more reliable financial risk estimation.

Computational feasibility for large and dynamic datasets is ensured through a combination of Markov Chain Monte Carlo methods and approximate approaches, including Integrated Nested Laplace Approximation (INLA). The analysis further distinguishes between intrinsic breach detection latency and strategic disclosure timing, incorporating time-varying covariates to capture changes in the regulatory environment. Overall, the framework delivers full posterior distributions for latent breach counts, enabling probabilistic assessment of reporting uncertainty and forward-looking evaluation of cyber exposure, with direct relevance for insurers, regulators, and risk managers operating in evolving disclosure landscapes. This is a joint work with Marco Pirra (University of Calabria, Italy) and Fabio Viviano (University of Calabria, Italy).

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 σ-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.

Joint work with Aleksandar Arandjelović.

A stochastic SIR model for cyber contagion: application to granular growth of firms and to insurance portfolio

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Abstract

This work stands on key empirical facts in economics and in cybersecurity. Economically, firm size and growth rate distributions are non-Gaussian and exhibit heavy tails (see [1] and [2]). In cybersecurity, contagion dynamics depend heavily on firm size and environmental conditions (see [3] and [4]). We propose a stochastic multigroup SIR model (inspired by [5]) integrated with a granular growth of firms (inspired by [6]) taking into account these behaviors. This allows us to define the financial impact of attacks on firms' revenue and insurance portfolio. In our model, a subunit's revenue suffers a random jump upon attack; the arrival time and the duration of this jump are defined using a sum of Cox process and a Bernoulli random variable. We provide theoretical results, including existence, uniqueness, stability of the SIR model, and additional asymptotic properties. Furthermore, we analyze the distinct effects of internal and external contamination. By governing SIR parameters with CIR dynamics, we incorporate environmental variability. This stochastic approach enables scenario generation and the calculation of the aggregate exceedance probability – a metric used in catastrophe modeling that gives an insurer immediate feedback on the financial nature of an event. We apply this framework to the Lockbit ransomware attacks between May and July 2024. For a portfolio of 2,929 firms located in Île-de-France, our model predicts that the insurer will have to compensate, with a 50% probability, up to 2 days of revenue for a 100-day cyber incident.

Joint work with Caroline Hillairet and Olivier Lopez.

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A general Multinomial model for causes of death

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Abstract

Understanding cause-specific mortality trends is essential for public health planning, life insurance, and pension systems, particularly as medical advancements continue to reshape global mortality patterns. Aggregate or all-cause mortality data are widely used to perform mortality analysis due to their accessibility. However, estimating mortality trends based solely on aggregate data can omit many important details that are available only in cause-of-death data.

Historically, the most intuitive approach to cause-of-death modeling involved independently forecasting mortality for each cause using time series methods, most popularly using uni-variate ARIMA time series models.

However, a reduction in one cause of death can potentially affect the other causes of death, leading to transfer of deaths to other causes. The Multinomial Logistic model is widely used in the literature to model multiple decrements allowing for the dependence between competing risks. This study shows that the Multinomial Logistic model is a special case of the Clayton Copula where the parameter capturing the dependence is equal to 1 and deaths transfer is proportional to the mortality rate of each cause. In the Clayton Copula model, stronger or weaker death transfers can be modelled via changing the value of this parameter.

Using the crude-net intensity relationship in the Clayton Copula, a General Multinomial model is developed, allowing for the parameter to capture deaths transfers between the causes. The proposed General Multinomial model allows to calibrate the parameter to the data, rather than fixing it subjectively as in the Clayon Copula. It can give important insights into death transfers between different causes. Illustrations are based on US causes of death data.

Neighbourhood-level mortality modelling using socio-economic indicators

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Abstract

In this study, we develop a modelling framework that quantifies the relationship between regional, demographic and socio-economic covariates through baseline mortality and age-related effects over time. This structure allows the influence of these components to be explained using spatial and socio-economic covariates that are fixed in time, such as those derived from census data that are not updated annually. Combining mortality modelling with machine learning techniques, the proposed framework isolates components of interest while allowing for a flexible class of models, including classical regression approaches, tree-based methods, boosting techniques, and generalized additive models, as well as hybrid combinations. Model performance is assessed using simulated data under controlled settings. The framework is then applied to real data to model mortality at the Lower Super Output Area (LSOA) level in the UK between 2001 and 2022, using socio-economic and demographic variables derived from census data. This application demonstrates how fixed regional characteristics can explain mortality variation at a granular spatial level.

Joint work with Ayse Arik and Andrés Villegas Ramirez.

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Incorporating frailty into multi population mortality models

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Abstract

This paper proposes a unified mortality modelling framework that merges the coherent multi population structure of [1] with the frailty based dynamics of the SAINT model [2]. Whereas coherent models typically assume homogeneous populations with stable age specific improvement patterns, frailty models capture heterogeneity, selection effects, and changing age profiles but are rarely applied across multiple countries. We incorporate frailty - static or dynamic - directly into a shared international mortality trend.

The approach enables country specific frailty parameters and allows inequalities in mortality to evolve over time. Bayesian smoothing of age effects reduces erratic country level patterns, and dynamic frailty processes help capture possible developments in the frailty distribution.

By combining coherence with realistic frailty driven age dynamics, the proposed model generates biologically plausible and stable long term projections for all ages, especially valuable for smaller or more volatile populations.

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Minimum Reversion in Mortality Models for Multiple Populations

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Abstract

After rescaling the period effects in an empirical study of mortality data in twenty countries over six decades, we observe that those effects show a pattern which is not always consistent with standard time series specifications that have been studied in the literature on actuarial mortality models.

We therefore propose a new multivariate time series model which incorporates the possibility that countries learn from others with lower mortality rates. This phenomenon corresponds to a "reversion to the minimum" which is interesting to study as a phenomenon in time series in its own right.

The model allows us to generate consistent mortality scenarios for multiple populations, and we find that our modification has a stabilizing effect on future mortality rates. We look at all-cause mortality statistics, but also investigate minimum reversion effects per cause of death for a subset of countries and time periods for which data per cause are available.

Joint work with Torsten Kleinow.

Global tail optimality and non exponential discounting

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Abstract

This paper revisits four notions of temporal consistency for intertemporal stochastic control with a general discount function: local and global tail optimality of a control plan, and local and global preference consistency of the agent. We introduce the notions of *decomposability* and of *super-* and *sub-decomposability* of the discount function, and we clarify how (and when) Bellman's principle of optimality extends beyond exponential discounting. When the discount function is non-decomposable, the problem becomes time-inconsistent and must be addressed through one of three canonical solution concepts—*precommitment*, *dynamically optimal (naive)*, and *Nash equilibrium (consistent planning)*. We characterize the implications of these three concepts and show that, for a broad class of non-decomposable discount functions, the Nash-equilibrium policy admits an *equivalent time-consistent representation* with decomposable discounting and an adjusted running utility. We illustrate the theory in a continuous-time consumption–portfolio choice model, derive closed-form rules, and show that under super-decomposability precommitment induces a uniformly higher propensity to consume than both the dynamically optimal and Nash-equilibrium strategies, while under sub-decomposability the reverse holds.

Joint work with Veronica Merlone and Lorenzo Maria Stanca.

Integrating Health Benefits into an NDC Pension System

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Abstract

Population ageing increases both pension and long-term care (LTC) expenditures, largely due to rising disability and illness at older ages. This paper proposes an extension of a notional defined contribution (NDC) pension system that incorporates health- and disability-contingent benefits throughout the retirement period. Using a continuous-time multi-state model of health, disability, and survival calibrated on data from the Health and Retirement Study, pension benefits are allowed to adjust dynamically to retirees' current health conditions, providing enhanced protection in fragile states. We formalize four key design objectives-financial sustainability, actuarial fairness, consistency with health-related economic needs, and homogeneity of benefits-and show that they cannot generally be satisfied simultaneously. Through a numerical analysis, we quantify the trade-offs implied by alternative pension designs and demonstrate how heterogeneity in longevity can be leveraged to finance enhanced benefits for unhealthy retirees without increasing aggregate pension expenditures, while making explicit the resulting redistribution across health states.

This is a joint work with Domenico De Giovanni (University of Calabria, Italy), Massimiliano Menzietti (University of Salerno, Italy) and Marco Pirra (University of Calabria, Italy).

Occurrence and reporting of property-related insurance claims using weather-related information

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Abstract

Weather events account for a substantial share of property-related insurance claims, making careful modelling of such claims crucial for prudent portfolio management. Highly granular open-source weather-related data are increasingly available at short notice, enabling new opportunities for improved claim development and reserving. In this paper, we provide a methodology to handle the claim dynamics of weather-related property insurance claims, i.e. the occurrence and reporting processes, and apply it to a real insurance portfolio. Specifically, we apply an EM-XGBoost framework, incorporating publicly available weather-related covariates such as precipitation and wind speed, enriched with date- and policyholder-specific information. Weather covariates are used directly to model the occurrence of claims, as well as indirectly to construct different reporting regimes for claims under varying weather conditions. Using data from multiple public sources, we assess the use of observational versus reanalysis weather data for both claim occurrence and reporting. Additionally, we examine the impact of temporal and spatial aggregation on model accuracy for IBNR reserving. This allows us to identify aggregation levels that still yield reliable estimates of occurrence and reporting dates while providing insights at both the individual and portfolio levels.

Joint work with Katrien Antonio, Gerda Claeskens and Koos Gubbels.

One-shot Individual Claims Reserving

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Abstract

Individual claims reserving has not yet become established in actuarial practice. We attribute this to the absence of a satisfactory methodology: existing approaches tend to be either overly complex or insufficiently flexible and robust for practical use. Building on the classical chain-ladder (CL) method, we introduce a new perspective on individual claims reserving. This new perspective creates a natural pathway for the application of machine learning techniques to individual claims reserving. As a proof of concept, we present a small-scale real data application employing simple linear regressions for individual claims reserving.

Joint work with Ronald Richman.

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Assessing continuous common-shock risk through matrix distributions

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Abstract

In this talk, we introduce a class of continuous-time bivariate phase-type distributions for modeling dependencies from common shocks. The construction uses continuous-time Markov processes that evolve identically until an internal common-shock event, after which they diverge into independent processes. We derive and analyze key risk measures for this new class, including joint cumulative distribution functions, dependence measures, and conditional risk measures. Theoretical results establish analytically tractable properties of the model. For parameter estimation, we employ efficient gradient-based methods. Applications to both simulated and real-world data illustrate the ability to capture common-shock dependencies effectively. Our analysis also demonstrates that common-shock continuous phase-type distributions may capture dependencies that extend beyond those explicitly triggered by common shocks.

Joint work with Martin Bladt and Oscar Peralta.

Pareto-Optimal Risk Sharing under Risk-Averse Preferences

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Abstract

We examine characterizations of Pareto-optimal risk sharing when agents' preferences are risk-averse. Specifically, we consider two broad classes of preferences, both of which admit the convex distortion risk measure as a special case. By introducing robustness to the distortion risk measure, we recover the class of coherent risk measures. While an explicit characterization of optimal allocations is difficult to obtain, we present an implicit result, as well as an efficient algorithm to solve for optimal risk-sharing allocations in this case. Our numerical results suggest that the structure of optimal allocations can be very complicated, even in relatively simple scenarios. On the other hand, introducing a utility function to the distortion risk measure gives the class of rank-dependent utilities, which is well-studied in the decision theory literature. In this case, we present a result linking Pareto-optimality of allocations to the Expected Shortfall. This characterization suggests a connection between allocations of the bang-bang type, which are common in the insurance literature, and the smoother allocation structures from expected utility theory. The first part of this talk is based on published work in this paper [1].

References

[1] Ghossoub, M., and Zhu, M.B. (2026). Efficiency in Pure-Exchange Economies with Risk-Averse Monetary Utilities. *Mathematical Finance* **36(1)**, pp. 99-117.

Optimal Underreporting and Competitive Equilibrium

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Abstract

This paper develops a dynamic insurance market model comprising two competing insurance companies and a continuum of insureds, and examines the interaction between strategic underreporting by the insureds and competitive pricing between the insurance companies under a Bonus-Malus System (BMS) framework. For the first time in an oligopolistic setting, we establish the existence and uniqueness of the insureds' optimal reporting barrier, as well as its continuous dependence on the BMS premiums. For the 2-class BMS case, we prove the existence of Nash equilibrium premium strategies and conduct an extensive sensitivity analysis on the impact of the model parameters on the equilibrium premiums.